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"CONSERVATION OF WILDLIFE THROUGH EDUCATION"

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THE FIRST FOUR YEARS OF KING SALMON MAINTENANCE BELOW SHASTA DAM, SACRAMENTO RIVER, CALIFORNIA[1]

By Dr. James W. Moffett
U. S. Fish and Wildlife Service
Stanford, California

INTRODUCTION

Water and its conservation for agricultural, power, and domestic purposes, have always been critical problems in California. Before the turn of the century, plans were being formulated for the storage and control of river discharges for beneficial use. A California State Water Plan (California Division of Water Resources, 1931) was ultimately derived in 1931 and federal assistance was sought to bring it to early realization.

One of the main features of this plan was the construction of Shasta Dam across Sacramento River and the formation of a 4,500,000 acre-foot capacity reservoir to store winter run-off, to control floods, to generate power, and to furnish water for irrigation, navigation and salinity control in summer when precipitation very rarely occurs.

Construction of Shasta Dam was virtually begun before the U. S. Bureau of Reclamation undertook to assess the effect of that structure on important fisheries and especially on the king salmon *(Oncorhynchus tschawytscha)* runs which had utilized the Sacramento River and its tributaries for ages. The State of California, in 1937, counted a portion of the salmon as they passed over Anderson-Cottonwood Irrigation District Dam about ten miles downstream from Shasta Dam. The Bureau of Reclamation began its study in 1938 and continued it until 1939, when it was taken over by the U. S. Bureau of Fisheries. The Bureau of Fisheries (Fish and Wildlife Service) maintained the count through 1939, 1940, 1941 and 1942.

Information in this report is the product of many persons. Mr. Harry A. Hanson, Dr. Paul R. Needham, Mr. Lewis Parker, Mr. Frederick K. Cramer, Mr. David F. Hammack, Mr. Reed S. Nielson, Dr. Oliver B. Cope, Dr. Osgood R. Smith and Mr. Daniel W. Slater formerly, or at present, on the staff of the U. S. Fish and Wildlife Service contributed much to this study. Data and suggestions were contributed by members of the California Division of Fish and Game. The Branch of Game-fish and Hatcheries in the Fish and Wildlife Service, and its district supervisor, Mr. John Pelnar, greatly increased the fund of information. Their part in the realization of this plan is worthy of special mention.

The U. S. Bureau of Reclamation, operators of the Central Valley Project, of which Shasta Dam is a unit, supported this study by transferring funds to the Fish and Wildlife Service. The service acts as the

[1] Submitted for publication December, 1948.

bureau's agent in studying and operating the fishery maintenance phases of the Shasta Project.

The Fish and Wildlife Service undertook a widespread study of Sacramento Valley streams and salmon life history in 1939, and prepared a preliminary biological report in 1940 which proposed several plans for salmon salvage (Hanson, Needham, and Smith, 1940). A summarization of this report was published in 1940 (Needham, Smith, and Hanson, 1940). These plans and much other evidence, including an extensive memorandum and plan prepared by Fred J. Foster, were reviewed by a Board of Consultants appointed by the Bureau of Reclamation. Prof. R. D. Calkins, Prof. W. F. Durand and Prof. Willis H. Rich, members of this board, issued a report in June of 1940, which set forth conclusions and recommendations for salmon maintenance and control. The board concluded that: (1) There are two salmon runs at Redding, California, a spring run, comprising five or six thousand fish, and a fall run, comprising fifteen to twenty thousand. (2) The salmon run to Redding forms not more than half of the total run propagating in the Sacramento River system. (3) The annual value to commercial fishermen of the upper Sacramento salmon may vary from $51,000 to $81,000. (4) The total values are increased to an unknown degree by values to sportsmen, the fishing trade, recreation, et cetera. (5) Two serious hazards to the success of any plan of salvage for salmon were recognized, namely, unscreened diversions and "snagging" on spawning beds.

The board recommended the adoption of the Sacramento River-Battle Creek-Deer Creek Plan which involved: (1) The placement of three racks in the Sacramento River, (2) the keeping of a count of salmon passing the lowermost rack and the combining of trapping facilities with one of the racks, (3) the construction of Coleman Hatchery, holding ponds at Darrah Springs and in Battle Creek, (4) the procurement of four trucks for hauling adult fish, (5) the liberation of young salmon from hatcheries in accord with the natural migration period, (6) the hauling of one-fourth of the spring run salmon to Deer Creek provided summer temperature conditions are satisfactory and (7) a continuing study of artificial propagation.

The board estimated: (1) The capital cost of the plan as outlined at $1,064,500 without Deer Creek holding ponds and $1,082,500 with such ponds, (2) the annual costs of operation at $35,000, and that, (3) these figures of capital expense and of annual cost are economically justified.

The board issued a supplemental report in October, 1940, in which suggestions by the State of California were considered. State suggestions were: (1) Provision for supplementary flow in Stillwater Creek by pumping from Shasta Reservoir, (2) experimental transport of adult salmon above Shasta Dam, (3) provision for expansion of hatchery facilities on Battle Creek and (4) additional trucks for transport of salmon.

The board ruled that: (1) The cost of pumping water to Stillwater Creek was excessive, (2) the transport of adult salmon above Shasta Dam might provide some useful information, (3) the possibility of enlarging Battle Creek Hatchery and the construction of a hatchery on Deer Creek should be entertained for the future, (4) the need for seven trucks for salmon transport was justified, (5) additional information should be

secured relative to the possibility of providing water from Sacramento River to maintain a permanent flow in Deer Creek, (6) continuous counting of salmon should be done at the lower and middle racks, (7) the suggested drafting of an agreement between the State of California and the Department of the Interior, defining the jurisdiction and the responsibilities of each agency, was not within the power of the board, (8) the Bureau of Reclamation should bear the expense of supplementary measures approved, (9) Keswick Dam should be built as a river flow regulating structure as well as a site for traps, (10) fourteen rearing ponds should be constructed at Battle Creek Hatchery instead of the eight previously recommended and (11) natural holding ponds in Battle Creek should be used for adult salmon.

The Maintenance Plan as Applied

The maintenance plan as evolved by later experimentation and study contained the following essential features by June 1, 1943, when it was placed in operation (cf. Needham, Hanson and Parker, 1943):

1. Fish ladder, traps and lifts in the Keswick afterbay dam and in the Balls Ferry Rack for trapping and removing salmon from the Sacramento River;

2. Seven tank trucks to transfer salmon from Keswick Dam and Balls Ferry to Battle Creek Hatchery and Deer Creek.

3. Facilities on Battle Creek as follows:

a. A hatchery having a capacity of about 58,000,000 eggs or advanced fry and such numbers of larger fingerlings as the facilities could provide;

b. Twenty-eight outdoor rearing and holding ponds;

c. A cold storage and ice-manufacturing plant;

d. Combined garage, shop and warehouse;

e. Dwellings for the operating personnel;

4. Five racks in main Battle Creek to form four holding and ripening pools for adult salmon.

5. Three Sacramento River racks complete with hoists and overhead cableway systems: the Balls Ferry rack, middle rack and the upper rack. The Balls Ferry rack had three uses: (1) As a trap, (2) as an aid to the distribution of salmon in the river for natural spawning, and (3) as a barrier to insure utilization of the riffles below Balls Ferry for spawning.

6. One rack with hoist and overhead cableway on Deer Creek to facilitate counting natural-run salmon and to prevent transferred fish from returning to the Sacramento River.

7. A fish ladder around the lower falls in Deer Creek to provide five miles of new spawning stream.

A hatchery in the Shasta plan was deemed essential by the Board of Consultants upon the recommendation of the Fish and Wildlife Service for the proper handling and perpetuation of the spring-run segment of the salmon population in Sacramento River. During the years 1943 and 1944, when Shasta and Keswick Dams were blocks to upstream migration but stored little or no water, river temperatures in summer were so high that the spring-run salmon would have been eliminated or seriously impaired had they been forced to remain below the dams over summer. It was imperative that these salmon be removed to cooler waters. The hatchery on Battle Creek was recommended for this purpose. Trans-

fer of salmon to Deer Creek for natural propagation was not a certain possibility at the time the hatchery was recommended.

Because of many delays imposed by wartime conditions, the Shasta Salmon Maintenance Program was not placed in operation until June 1,

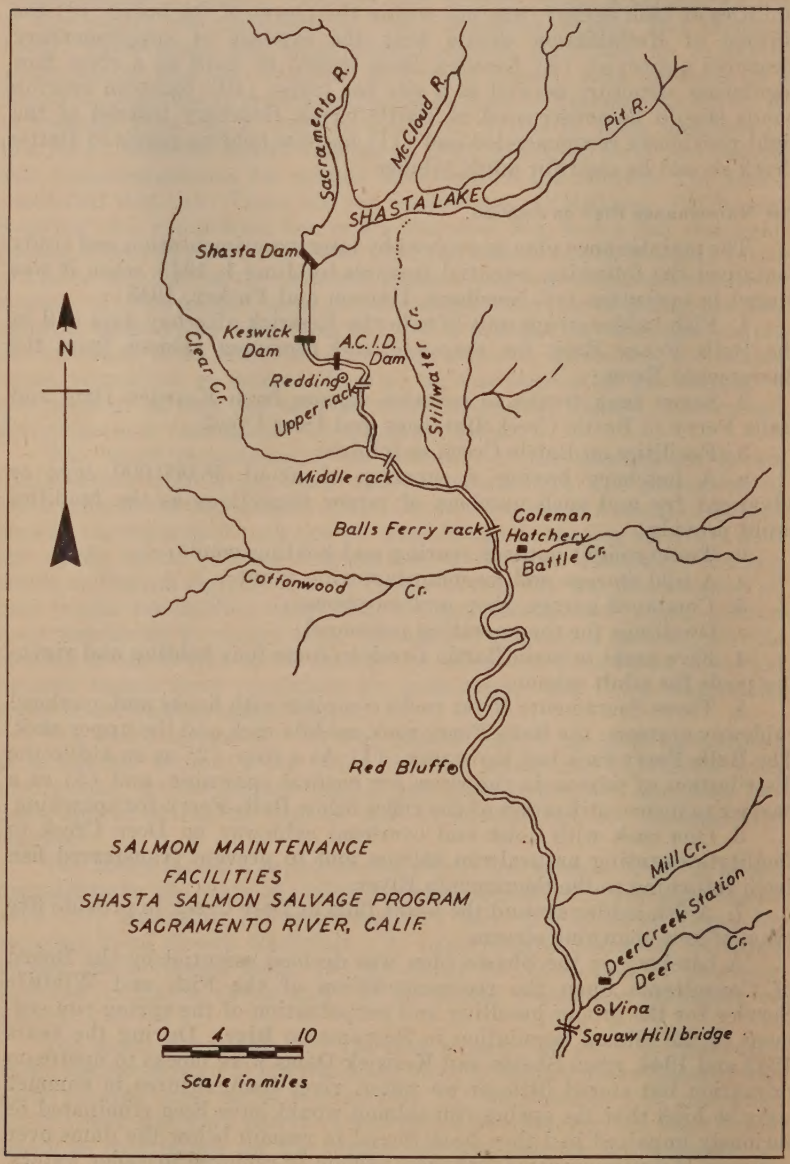

FIGURE 15. Salmon maintenance facilities, Shasta Salmon Salvage Program, Sacramento River

1943. Even at that time, many facilities were not completed and it was necessary to make improvisations and adaptations of inadequate equipment which, at times, threatened the very operation of the undertaking.

OPERATION OF THE MAINTENANCE PLAN

Salmon Population Handled

The number of adult salmon entering Sacramento River above the mouth of Battle Creek each year varied considerably. However, in all years they exceeded the estimate of the board of consultants and all counts of salmon made at the Anderson-Cottonwood Irrigation District Dam. Attempts to count the fall-run segment of this population at Balls Ferry rack were made in 1943, 1944 and 1945, but high water and poor rack substratum detracted materially from the reliability of the counts made. The only fairly complete count was obtained in 1943, when Balls Ferry was first installed. In that year the rack was installed September 20th, and was removed December 17th. Trouble was experienced in keeping the rack fish-tight while it was in place.

Numbers of adult salmon counted or handled at Keswick Dam and Balls Ferry rack are presented in Table 1. Counts of salmon through Balls Ferry rack during November and December were obtained only in 1943. In those months, 27.9 percent of the fall run was counted. The fall runs of 1944 and 1945, although not counted in November and December, presumably migrated according to the 1943 pattern. On this assumption, the actual count for those years when increased by 27.9 percent to account for the missing months, should approximate the total numbers of salmon involved. When so adjusted, the total salmon run above Balls Ferry rack for 1944 amounted to 83,286 and that for 1945 approximated 55,979.

Estimates of the total number of salmon above Red Bluff, California, have been made since 1943. These estimates, which include the population of Battle Creek, were set conservatively at 144,000 for 1944, 106,000 for 1945, and 96,900 for 1946. In making the estimates all known counts were totaled and augmented by numbers fixed by visual observations and counts made on spawning beds.

The known numbers of salmon handled or counted during the operation of the Shasta Project were distributed to three places: viz., Sacramento River, Deer Creek and Coleman Hatchery. A summary of this distribution is made in Table 2.

Coleman Hatchery Operations

The disposition of salmon hauled to Coleman Hatchery from the Sacramento River and the native spring run trapped in Battle Creek since the station began operations is summarized in Table 3.

If the unaccountable losses are disregarded and the number of females spawned, plus the known mortality, is assumed to be the female population available for egg take, then the average percentage of females spawned from transferred lots of salmon during 1943, 1944 and 1945 is 48.8 for spring run and 60.7 for fall run. The records for 1946 fall-run salmon were not used in the computation because most of the fish were taken from Battle Creek native stock.

Because of crowding at Keswick Dam, 7,536 fall-run salmon were transferred to Coleman Hatchery November 4-26, 1946. Only 2.8 percent

TABLE 1

Numbers of Salmon Counted or Trapped in Shasta Salmon Maintenance Program*

Month	1943			1944			1945			†1946
	Keswick Dam	Balls Ferry Rack	Total salmon	Keswick Dam	Balls Ferry Rack	Total salmon	Keswick Dam	Balls Ferry Rack	Total salmon	Keswick Dam
January										
February							16		16	
March							185		185	
April				91	26	117	87		87	
May				334	4,043	4,377	97	660	757	20
June	5,245		5,245	528	3,666	4,194	68	1,349	1,417	147
July	440		440	409	1,183	1,592	199	769	968	322
August	139		139	847	955	1,802	242	60	302	330
September	432	1,619	2,051		8,230	8,230		3,989	3,989	1,467
October	78	24,497	24,575		49,169	49,169		36,611	36,611	105
November		8,573	8,573				320		320	7,536
December		341	341							
Totals	6,334	35,030	41,364	2,209	67,272	69,481	1,214	43,438	44,652	9,927
Annual totals			41,364			69,481			44,652	9,924

* Balls Ferry rack was in operation:
September 20-December 17, 1943—counting period—September 20-December 8
April 27-November 9, 1944—counting period—August 30-October 31
May 26-October 29, 1945—counting period—September 4-October 30
† Balls Ferry rack was not in operation during 1946.

TABLE 2

Summary of the Distribution of Salmon Counted or Handled in the Shasta Salmon Maintenance Program

Year		To Deer Creek	To Coleman	To Sacramento River	Total salmon handled	Annual total	Percentage of total run	
							Handled at Coleman	Handled at Deer Creek
1943	Spring	5,245	944	Unknown	6,189			
	Fall		9,648	25,805	35,453	41,642	25.4	12.6
1944	Spring	8,034	4,048	Unknown	12,082			
	Fall		10,341	47,058	57,399	69,481	20.7	11.6
1945	Spring	1,606	2,127	Unknown	3,733			
	Fall		11,335	29,585	40,920	44,653	30.1	3.6
1946	Spring	167	2,224	Unknown	2,391			
	Fall		7,536	No count	7,536	9,927		

TABLE 3

Records of Adult Fish Handled at Coleman Hatchery 1943-1946, Inclusive*

Year	Lot Number	Source	Run	Number fish impounded	Number of females spawned	Excess males[1]	Known males	Mortality females	Unaccountable loss[2]
1943	1	Native	Spring		227				
1943	1A	Keswick	Spring	944	27	17	280	(Sex unknown)	620
1943	2	Balls Ferry	Fall	[3]4,275	789	2,083	800	583	20
1943	3	Balls Ferry	Fall	5,373	752	1,132	654	249	2,586
1944	4	Native	Spring	1,181	116	689	158	205	12
1944	5	Keswick-B.F.	Spring	4,045	732	1,488	617	654	554
1944	6	Balls Ferry	Fall	10,016	2,006	4,535	1,168	1,254	907
1945	8	Native	Spring	468	31	144	143	53	111
1945	9	Keswick-B.F.	Spring	1,777	224	215	559	335	444
1945	10	Keswick-B.F.	Fall	11,274	2,966	3,204	2,517	2,133	454
1946	12	Native	Spring	2,450	328	991	570	481	80
1946	13	Keswick	Spring	2,118	236	1,107	434	260	81
1946	14	Native	Fall	[4]534	39	534	46	8	3
1946	14	Native	Fall	[5]10,197	1,762	4,283	337	171	[6]3,644
1946	15	Keswick	Fall	7,536	2,379	4,361	384	69	[7]343

* Records in this table were summarized by Dr. Frederic F. Fish.
[1] Frozen for fingerling fish food.
[2] Includes some fish known to have spawned naturally.
[3] Impounded in hatchery rearing ponds.
[4] Returned to hatchery rearing ponds.
[5] Impounded at Old Battle Creek Hatchery.
[6] Includes 3,551 released to spawn naturally.
[7] Includes 337 released to spawn naturally.

TABLE 4

Résumé of Egg, Fry, and Fingerling Production, Coleman Hatchery, 1943-1946, Inclusive *

Brood year	Lot Number	Source	Run	Number green eggs collected	Number fry produced	Number fingerlings released	
						First spring	First fall
1943	1-1A		Spring	1,053,665	837,984	714,205	47,358
1943	2	Balls Ferry	Fall	4,307,141	3,999,629	3,804,311	129,867
1943	3	Balls Ferry	Fall	4,013,712	3,775,732	3,728,472	0
1944	4	Native	Spring	476,666		408,922	0
1944	5	Keswick	Spring	3,563,984	3,051,539	2,585,935	170,011
1944	6	Balls Ferry	Fall	11,298,880		10,019,419	256,867
1944	7	Native	Fall	[1]193,600	181,200	176,970	0
1945	8	Native	Spring	127,668	120,256	87,863	24,930
1945	9	Keswick-B.F.	Spring	1,153,604	1,038,559	682,853	202,105
1945	10	Keswick-B.F.	Fall	20,579,463	18,060,609	16,916,376	691,373
1945	11	Native	Fall	[1]3,256,000	3,255,800	3,221,600	0
1946	12	Native	Spring	1,476,000	1,371,603	986,116	297,338
1946	13	Keswick	Spring	1,287,000	1,189,586	823,003	277,205
1946	14	Native	Fall	11,131,000	10,775,000	9,625,338	301,009
1946	15	Keswick	Fall	14,403,000	13,887,314	13,185,250	289,982

* Records in this table were summarized by Dr. Frederic F. Fish.
[1] Received from Battle Creek Hatchery as eyed eggs.

of the females in this lot were lost before spawning. These salmon were held a minimum of time at the hatchery. The contrast between their survival and that of lots held during previous years indicates that artificial transfer and holding are responsible for much of the mortality of brood salmon prior to spawning.

The numbers of eggs, fry and fingerlings produced from the lots of fish spawned at Coleman Station since the beginning of operations are given in Table 4.

All of the young salmon produced in the hatchery were held until they had been feeding for some time. It was reasoned that by following this practice the young fish would have a better chance for survival after being released. All releases of regular production stock were made into Battle Creek and without exception before April 15th, so that seaward migration could coincide with natural migrations and be well underway before heavy irrigation demands removed large quantities of water and fish from Sacramento River. Experimental lots, held and fed over summer, were not released until after October 15th, when the irrigation demand had ceased or at least diminished. Comparable, representative lots of 50,000 spring and fall fish were marked. Two such lots from the 1944 brood and four lots from the 1945 brood were handled in this manner.

Production of young salmon in the hatchery once the eggs were secured has been quite successful. The average mortality from the green-egg state to the fry stage approximates 7.6 percent, that from the fry to fingerling (release) stage is about 2.7 percent.

Main River Spawning Plan

The major portion of the Sacramento River salmon population was accommodated by the main river spawning plan. In accordance with the plan, racks were installed in Sacramento River at Balls Ferry and at the Middle Rack site about twelve miles upstream. A third rack proposed for a site near Redding, California, was not installed. Its construction was deferred until a definite need for it was demonstrated by plan operation.

Neither of the two racks placed in the river functioned satisfactorily. They either washed away or were exceedingly difficult to make fish-tight. The Middle Rack was first installed October 12-15, 1942, and on November 19th was washed out by rising water. It was installed August 26th and removed by high water on November 20, 1943. In 1944, the rack lasted from September 13th to November 29th when it was removed. However, a storm on October 30th made it ineffective. About the same thing happened in 1945 when the rack remained in the river from September 11th to October 29th. Bottom conditions at the rack site became increasingly worse following each washout, and by the 1946 season the rack could not be installed.

The trouble encountered with Balls Ferry rack began before it was used the first time. A small flood in the winter of 1942-43 removed several of the pile bents on which the rack structure was to rest. In 1943, the rack was placed September 20th, and removed December 17th. In 1944, it functioned between April 27th and November 9th, when a flood removed it from the river. In 1945, the rack functioned only partially over the period May 26th to October 29th. On the latter date the rack

was completely demolished by floods. The river bottom at the site was so seriously rutted that the rack was not used in 1946.

The Upper Rack was never built although a need for it became apparent in 1945 and 1946 when undesirable concentrations of fall-run salmon occurred at the base of Keswick Dam. The site for this rack was found to be poorer in all respects than that of the Middle Rack and it was considered a waste of money, equipment and time to place the structure. Instead, negotiations were begun to gain permission from the Anderson-Cottonwood Irrigation District to use its dam at Redding as an upstream block or upper rack.

The total salmon population allowed to spawn in the Sacramento River between Balls Ferry and Keswick Dam is undoubtedly greater than the estimates assumed for 1944, 1945 and 1946. The decrease in Sacramento River water temperature following storage in Shasta Reservoir influenced the behavior of spring-run salmon so that they practically ceased active migration to the upper river and to the trapping facilities at Keswick Dam. These salmon could not be counted because of their dispersal, but annual observations of riffles at spawning time indicated a great abundance.

Success of the Main River Plan

Proof of the relative success of the main river plan, like that for the success of the Coleman Hatchery, remains to be obtained. Ultimate returns to the spawning grounds and to the salmon fishery will furnish the proof. It is interesting to note that the 1946 commercial catch in California amounted to 13,700,000 pounds, the largest take in 31 years of record. The major portion of these salmon was produced in 1941, 1942 and 1943. It is evident that the 1942 age class attributable to Sacramento River was produced below Keswick Dam which became a barrier in May of 1942.

Observations made on the operation of the river plan suggest a certain degree of success. Examinations of dead salmon recovered from the river reveal that a great percentage of the female salmon deposited their eggs. Yearly fyke-net fishing in the river at Balls Ferry indicates that millions of young salmon migrated seaward.

Dead salmon lodging on Middle and Balls Ferry racks were examined to determine the degree of spawning success achieved by the population using the main Sacramento River spawning gravels. In 1943 (between November 10th and December 11th) 1,233 males and 388 females were examined. Difficulties were encountered in determining the condition of the males but 367 of the 388 females, or 94.6 percent, had spawned completely.

Recoveries were made in 1944 during the period October 30th through November 29th. They amounted to 2,158 salmon, of which 1,521 were males and 637 were females. Only 428, or 67.2 percent, of the females were spent while 209, or 32.8 percent had not spawned at all. The majority of the unspent females was recovered between November 4th and 10th, immediately following the first heavy rain of the winter season, which fell on November 2nd. Practically the entire run-off of that storm above Shasta Dam was stored in the reservoir and run-off below the dam brought toxic pollutants into the river from stored smelter flue dust and from copper leachings in abandoned mine tunnels. The reduced flow in

Sacramento River for several miles below Shasta Dam was insufficient to dilute the pollutants and heavy mortalities among the adult fish resulted. By deleting the females recovered between November 4th and 10th, the percentage of unspent females is reduced to 16.2.

High water and floods in Sacramento River during the 1945 fall season restricted the examination of dead salmon to the period: October 17th-30th, both dates inclusive. In that time, 760 males and 376 females were examined. Of the 376 females, only six (1.8 percent) were unspent.

These studies indicate clearly that spawning in that portion of Sacramento River between Balls Ferry and Keswick Dam is successful, especially when extraneous causes of mortality are eliminated or held at a minimum.

A hoop net with an opening five feet in diameter and covered with one-fourth inch bar mesh webbing has been fished in the same location at Balls Ferry since the first season of Shasta plan operation. Records of catches obtained from the 1943 and 1944 broods are somewhat fragmentary, but samples from the 1945 and 1946 broods are practically complete. Summaries of the results obtained are presented in Table 5.

TABLE 5

Fyke-Net Record Summary—Balls Ferry

Time period	Hours fished	Total catch	Catch per hour	Average length in mm.
Brood Year 1943				
1/17-31	221	391	1.8	36.6
2/1-14	47	96	2.0	36.8
2/15-29	224	1,691	7.5	36.8
3/1-14	113	367	3.2	37.7
3/15-20	32	33	1.0	37.0
Totals	637	2,578		
Mean			4.0	36.8
Brood Year 1944				
12/7-19	217	12	0.05	32.2
12/24-31	56	20	0.36	
1/1-10	158	373	2.36	
1/11-20	175	1,389	7.93	
1/21-31	150	1,936	12.90	
2/1-10	51	161	3.15	
2/11-20	52	554	10.65	
2/21-28	120	1,049	8.74	
3/1-10	85	984	11.57	
3/11-20	120	1,174	9.78	
3/21-25	34	309	9.09	
Totals	1,218	7,961		
Mean			6.54	
Brood Year 1945				
1/16-22	105	114	1.08	38.3
1/23-29	105	401	3.81	38.4
1/30-2/5	105	811	7.72	39.1
2/6-12	105	780	7.43	39.5
2/13-19	105	657	6.26	39.0
2/20-26	105	1,249	11.89	39.5
2/27-3/5	90	854	9.49	39.0
3/6-12	105	780	7.43	38.9
3/13-19	105	519	4.94	38.8
3/20-26	105	531	5.05	38.7
3/27-4/2	105	1,034	9.85	39.5
4/3-9	105	273	2.60	40.3
4/10-16	105	187	1.78	42.1
4/17-19	45	83	1.84	46.1
Totals	1,395	8,273		
Mean			5.93	39.9

Time period	Hours fished	Total catch	Catch per hour	Average length in mm.
Brood Year 1946				
12/11-15	75	632	8.4	37.2
12/16-20	75	3,982	53.1	37.5
12/21-25	75	4,234	56.5	37.5
12/26-30	75	3,783	50.4	38.0
12/31-1/4	75	4,000	53.3	38.2
1/5-9	75	1,909	25.4	38.7
1/10-14	75	1,387	18.5	38.7
1/15-20	90	3,291	36.6	38.7
1/21-25	75	2,312	31.0	38.9
1/26-30	75	1,077	14.1	39.8
1/31-2/4	75	2,205	29.4	38.7
2/5-9	75	1,924	17.1	38.6
2/10-14	45	457	10.2	38.6
2/15-19	75	1,634	21.8	39.0
2/20-24	75	778	10.4	38.8
2/25-3/1	75	620	8.3	38.8
3/2-6	45	223	5.0	40.0
3/7-11	45	61	1.4	42.1
3/12-16	75	227	3.0	40.8
3/17-21	75	34	0.5	45.2
3/22-26	75	41	0.6	39.3
3/27-31	75	12	0.2	43.0
4/1-5	60	81	1.4	43.1
4/6-10	75	9	0.2	48.8
4/11-15	75	8	0.1	39.9
4/16-19	60	28	0.5	44.0
4/21-29	52	5	0.1	56.4
5/1-8	66	4	0.1	60.5
5/21-6/4	63	0	0.0	00.0
Totals	2,026	34,958		
Mean			17.3	38.4

Application of these data in the derivision of total numbers of downstream migrants produced in Sacramento River above Balls Ferry is not advisable. Many factors, such as river flow, presence of debris, muddy water, and net location, influence the efficiency of such a net to a great extent. Furthermore, the net does not effectively capture larger fish. However, comparison of the number of adult salmon counted or estimated above Balls Ferry with the rate of catch (catch per hour) obtained while sampling their offspring, shows a rather striking agreement and lends some credence to the use of population samples taken in this manner as a relative measure of the magnitude of seaward migration.

The yield of seaward migrant salmon by the river is apparently rather large. Records covering the migration of the 1946 brood past Balls Ferry, for example, demonstrate that great numbers of young salmon must have been in the river at times. Catches made by an identical net fished during the same period at Squaw Hill Bridge, about sixty miles downstream from Balls Ferry, demonstrate a peak in abundance six weeks later but otherwise similar to the Balls Ferry peak. During 34 hours of fishing at Squaw Hill Bridge, February 5th-9th, there were 3,674 young salmon captured. Neither of these records was influenced by hatchery releases.

Deer Creek Natural Spawning Plan

Experiments conducted in 1941 successfully demonstrated the feasibility of transferring Sacramento River king salmon from Keswick Dam and Balls Ferry rack to Deer Creek about 94 miles below Shasta Dam (Parker and Hanson, 1944). As a result, that part of the spring run trapped at Balls Ferry rack and at Keswick Dam prior to June 15th or 30th, depending on the year, was moved to Deer Creek.

A native run of spring salmon already utilizes Deer Creek. Enumeration of this run prior to the maturation of progeny from transferred salmon was considered essential if the relative success of the rehabilitation program were to be learned. Consequently, the native fish have been counted through a rack each year since 1941. Counts are incomplete, however, results obtained each year as well as the numbers of salmon hauled to the stream are presented in Table 6.

TABLE 6

Spring-Run Salmon Counted or Handled at Deer Creek

	1941	1942	1943	1944	1945	1946	Totals
Salmon counted*	635	1,108	812	2,692	3,563	4,257	13,067
Salmon hauled†	920	None	5,245	8,034	1,606	167	15,972

* Periods of counting: May 3-July 6, 1941; May 5-July 3, 1942; February 20-22, March 2-5, March 20-June 16, 1943; January 1-11, January 24-26, January 30-February 2, February 22-25, February 28-March 3, March 10-June 30, 1944; April 13-June 23, 1945; April 11-June 29, 1946.

† Periods of hauling: June 3-30, 1941; June 1-29, 1943; April 22-June 28, 1944; March 12-June 15, 1945; May 6-June 15, 1946.

Losses of transferred adult salmon in Deer Creek were especially heavy in 1943. Delays in the start of hauling forced holding of many salmon at Keswick Dam where they gradually deteriorated. Many difficulties in operation further aggravated the poor condition of the fish.

Between June 1st and June 30th, there were 5,245 salmon hauled to Deer Creek and by July 21st the known mortality was 1,273 or 24.4 percent.

The transfer operations of 1944 were much more effective and observable mortalities in Deer Creek remained almost negligible until the day on which hauling was stopped. On June 28th, when water temperatures in Deer Creek rose to 82 degrees F., 7,868 salmon had been released into the stream and only 128, or 1.6 percent had died following release. But, during the three days, June 28th-30th, high water temperatures killed 1,135 fish that had not reached the seclusion and safety of Deer Creek Canyon. The loss raised the 1944 mortality to 1,263 or 16 percent.

Mortalities among the 1,606 salmon hauled in 1945 were almost negligible. Only eight salmon of that number died shortly after hauling. Practically no salmon were hauled to Deer Creek in 1946. However, of the 167 transferred, only one was lost.

Repeated patrols of Deer Creek showed that once salmon reached the cold water of the canyon, mortalities were not serious. Some mortality resulting from mechanical injury was noted in 1943, 1944 and 1945. The 1943 salmon suffered many injuries before being transferred. Injuries in 1944 and 1945 were confined chiefly to the native stock which had difficulty crossing the Stanford-Vina Dam, a diversion structure across the lower reach of Deer Creek.

Fyke nets were fished in Deer Creek about three miles above its mouth each season of seaward migration since 1941. A summary of the catches and the hours fished is given in Table 7. The seaward migration usually begins in January, increases in intensity through February and reaches a peak in mid-March. It then decreases rather markedly, but continues sporadically until about the middle of May.

TABLE 7

Results of Fyke-Net Fishing for Seaward Migrant Salmon in Deer Creek

Brood year	Number of migrants caught	Period of fishing	Hours fished	Catch per hour
1941	346	1/14-6/ 6/42	3,519	0.10
1942	99	2/10-6/ 7/43	1,657	0.06
1943	1,590	1/ 1-5/31/44	3,978	0.40
1944	2,498	1/ 1-6/30/45	3,806	0.66
1945	585	1/ 1-6/16/46	2,463	0.24
1946	272	1/ 1-5/20/47	1,773	0.15
Totals	5,390		17,196	
Mean				0.31

Many seaward migrant salmon produced in Deer Creek are lost in the irrigation diversions which take practically all of the stream by the end of May each year. Periodic fishing in one diversion during 1945 is summarized in Table 8, and presents a good example of the potential loss of young fish in such diversions.

TABLE 8

Summary of Catches of Young Salmon in Diversions from Deer Creek

Date	Number of salmon	Hours fished	Catch per hour
January 25-31	4	119	0.03
February 1-28	41	360	0.11
March 1-31	45	570	0.079
April 1-27	3	378	0.008
Totals	93	1,427	0.065 (Mean)

It was recommended by the board of consultants that the need for additional water in Deer Creek be investigated. In the event of such a need, a method was to be devised whereby water could be supplied to irrigation interests from Sacramento River and a continuous and ample natural flow maintained in Deer Creek for the perpetuation of salmon.

Each year since operations began and prior thereto, adult salmon have had difficulty negotiating the Stanford-Vina Dam, lowermost of two diversion structures on that stream. A low standard fish ladder over this dam operated occasionally, but usually the fish battered themselves to death or sustained major injuries on the shallow apron of the dam. This condition was alleviated in 1946 when the State of California built a functional ladder.

Often, when flow in the stream diminished and irrigation demands increased, the creek became so warm (Fig. 16) that it killed the late arrivals before they could ascend the dam. Close inspection of Deer Creek below this dam, June 21st-23d, 1945, revealed 283 adult salmon dead. The situation was worse in 1946, when, despite rescue efforts, 473 adult salmon died on June 24th. By May 20th, in 1947, water temperatures were high enough to kill 108 salmon between the mouth of Deer Creek and the fish-counting weir.

The downstream migration of young salmon and steelhead trout, as pointed out, is seriously reduced by irrigation diversions at the Stanford-Vina Dam, despite the operation of so-called screens in all ditches. The loss of young fish in diversions is aggravated in years of low precipitation because irrigation demands begin earlier than usual and almost all of the stream flow is taken while the migrants are still moving down in large numbers. The California State Division of Fish and Game has appropriated money for the reconstruction of screens and by-passes on diversions from Deer Creek. Actual construction is now being undertaken. The added improvement should contribute materially to the success of the salmon population using Deer Creek.

Losses of adult and young salmon in Deer Creek cast doubt on the ultimate success of the transfer activities. The only actual improvement made to accommodate the additional salmon placed in Deer Creek was the construction of a fish ladder over lower falls which provided five miles of new spawning and nursery stream. The new stretch of stream was first used by salmon in 1944.

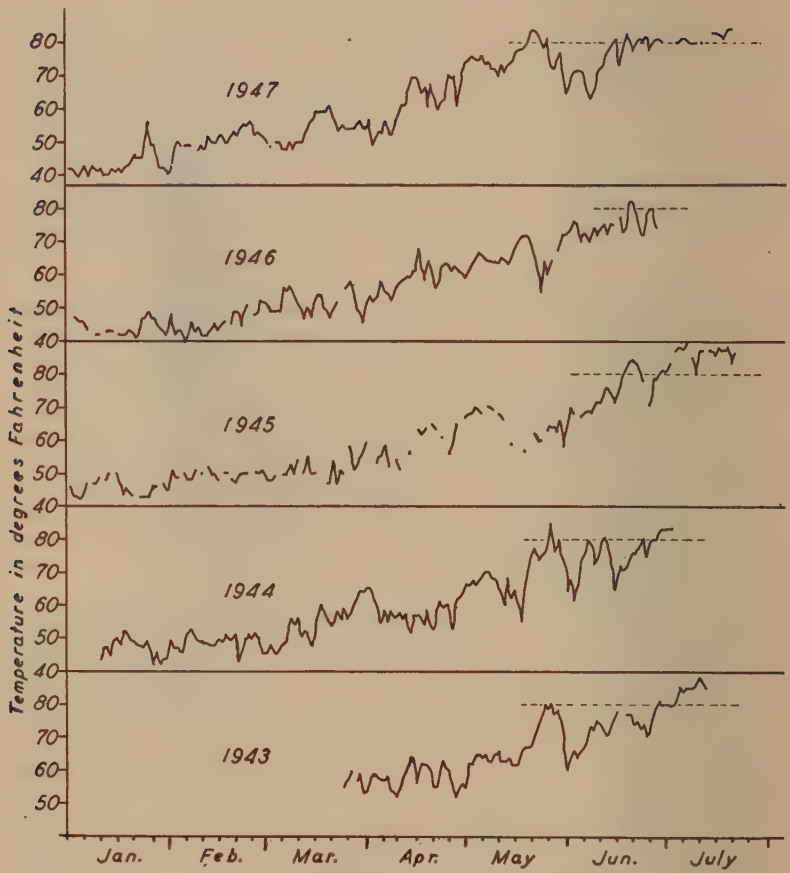

FIGURE 16. Maximum daily water temperatures in Deer Creek, a tributary to Sacramento River

It is generally conceded that a population exists at its maximum level at all times, considering *all* environmental factors, except during periods of adjustment usually established by activities of man. On this premise it can be assumed that the average salmon population in Deer Creek was as large as it could be without some controlling factor or factors being adjusted. Additional populations of the same species and habits superimposed on the native populations are doomed to gradual or even rapid extinction unless conditions under which both populations are forced to survive are changed sufficiently to accommodate them.

Repeated surveys of spawning grounds and natural holding areas in Deer Creek have furnished the conclusion that ample space is available for more than fifteen thousand spawning salmon. Water temperatures in the canyon are satisfactory for holding and egg incubation. Floods do not menace the riffles until the hatching period is practically completed. Stream run-off, even in dry years, is sufficient to support and maintain a large run of spring salmon and many fall salmon which now are prohibited from using the stream except during years of maximum rainfall.

All of the studies and investigations made at Deer Creek indicates the necessity for three improvements: (1) Development of an irrigation water supply from Sacramento River for farms in the drainage which would permit the natural flow of Deer Creek to reach the river; (2) judicious channelization of Deer Creek from Sacramento River to the mouth of its canyon; and (3) removal of all dams and obstructions now impeding movement of fish up and down stream.

ECOLOGICAL CHANGES IN SACRAMENTO RIVER BELOW SHASTA DAM

The Sacramento River below Shasta Dam has undergone rather radical changes since the operation of Shasta Reservoir began. The most obvious of these changes are: (1) reduction in water temperature during summer and increase in water temperature in winter; (2) alteration of run-off patterns; and (3) removal of much silt from the water.

Water Temperatures

Changes in river temperatures have been most striking. As demonstrated in Figure 17, the temperature of water released from Shasta Reservoir decreased from a range of 61-64 degrees F. in August, September, and October of 1944, when the reservoir stage was between 875 and 880 feet above sea level (dead storage level 828) to 57 degrees F. in the same months of 1945 when the reservoir stage was 965-970, and to 55.5 degrees F. in the same months of 1946 when the reservoir stage was 970-975 (data from Bureau of Reclamation records).

Maximum daily water temperatures at Balls Ferry, 35 miles below Shasta Dam, have never risen above 63 degrees F. since early December of 1944, when a continuous record was started. In 1945, the maximum daily temperature was 60 degrees F. or below on all but 50 days and during 1946 the maximum daily temperature never reached 60 degrees F. Peculiarly enough, summer maxima remain comparatively constant. During the months of May through October, the extremes were 53 degrees F. and 63 degrees F. in 1945 and 50 degrees F. and 59.5 degrees F. in 1946.

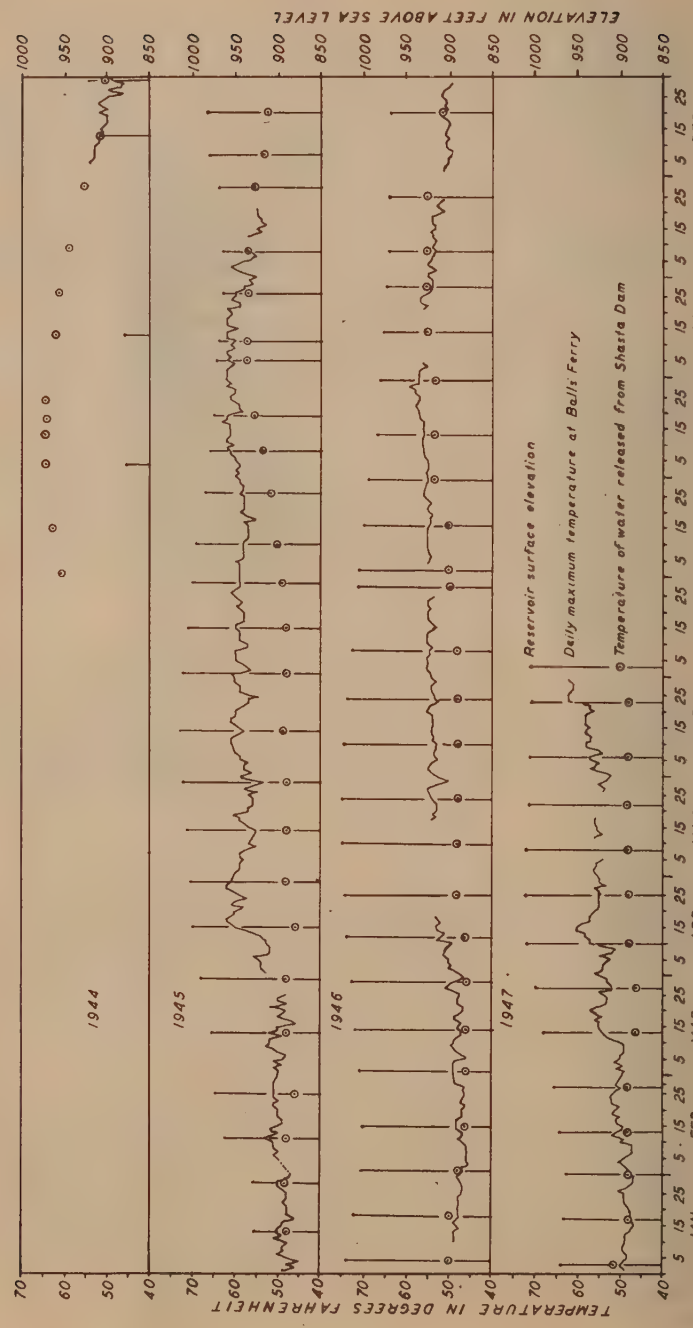

FIGURE 17. Shasta Reservoir surface elevation, temperature of water released from Shasta Dam and maximum temperature of Sacramento River at Balls Ferry

The heat stored in waters of Shasta Reservoir throughout summer is influential in maintaining higher temperatures in Sacramento River long after climatic conditions would have normally cooled the stream to well below 50 degrees Fahrenheit (Figure 18). Water released from Shasta Dam in November and December has never been colder than 51 degrees Fahrenheit and it has been as warm as 59 degrees Fahrenheit. Usually, the release from the reservoir constitutes almost the entire flow of the river during these months except when storms of short duration activate dry tributary streams. Cool nights and days tend to dissipate the heat contained in the river water, but the reservoir's influence is still perceptible many miles below the dam.

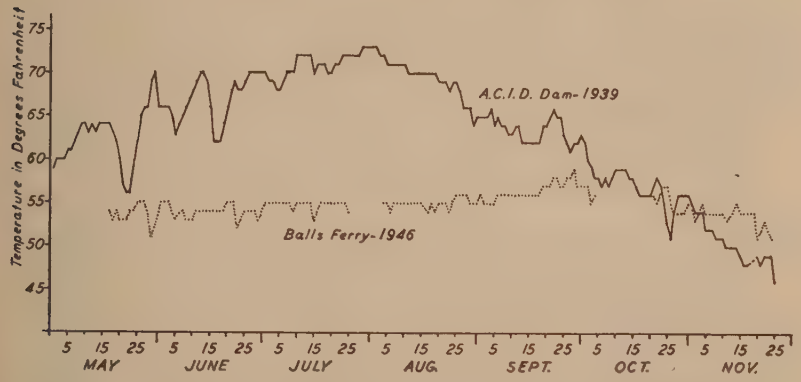

FIGURE 18. Maximum daily temperatures of water in Sacramento River before and after operation of Shasta Reservoir

Water temperatures in Sacramento River were not recorded during the winter and spring months prior to construction of Shasta Dam, but maximum daily temperature readings are available for the summer of 1939 at Anderson-Cottonwood Irrigation District Dam and for the summer of 1941 at Balls Ferry, 18 miles downstream. These records are compared in Table 9, with daily maxima recorded at Balls Ferry in 1946, to illustrate the changes which have occurred in the river's thermal characteristics. The magnitude of the temperature differences is shown graphically in Figure 18, which depicts the 1939 temperatures at Anderson-Cottonwood Irrigation District Dam and the 1946 temperatures at Balls Ferry. Average daily maxima at the Irrigation Dam in 1939 for each month during the period are higher than similar averages for Balls Ferry in 1946 by 8.9 degrees in May, 13 degrees in June, 16.1 degrees in July, 14.5 degrees in August, 7.1 degrees in September, 1.6 in October and lower by 3.1 degrees Fahrenheit in November. A similar comparison between the 1941 and 1946 records made at Balls Ferry shows the 1941 averages to be higher by 15.8 degrees in August, 5.9 degrees in September and 0.2 degrees Fahrenheit in October.

Run-off Patterns

The flood control and conservation storage features and the water release schedules of Shasta Reservoir have changed run-off patterns

TABLE 9

Maximum Daily Water Temperatures in Sacramento River at the Anderson-Cottonwood Irrigation District Dam and at Balls Ferry Before and After Operation of Shasta Reservoir

Day of month	May		June		July		August			September			October			November	
	ACID Dam 1939	Balls Ferry 1946	ACID Dam 1939	Balls Ferry 1946	ACID Dam 1939	Balls Ferry 1946	ACID Dam 1939	Balls Ferry 1941	Balls Ferry 1946	ACID Dam 1939	Balls Ferry 1941	Balls Ferry 1946	ACID Dam 1939	Balls Ferry 1941	Balls Ferry 1946	ACID Dam 1939	Balls Ferry 1946
1	59	-------	66	55	70	55	73	72	-------	65	64	56	62	60	57	55	55
2	60	-------	66	55	69	55	73	73	-------	65	65	55	60	61	57	54	53
3	60	-------	66	55	69	55	72	72	-------	65	66	55	59	61	55	54	54
4	60	-------	65	54	68	55	72	72	55	66	67	55	58	59	56	54	55
5	61	-------	63	53	68	55	71	73	55	64	-------	55	58	58	-------	52	54
6	61	-------	64	-------	69	55	71	72	54	65	-------	56	57	58	-------	52	54
7	62	-------	65	54	70	55	71	72	55	64	-------	56	58	56	-------	52	54
8	63	-------	66	53	70	55	71	72	55	64	-------	56	57	56	-------	51	54
9	64	-------	67	53	70	54	71	72	55	63	-------	56	58	56	-------	51	54
10	64	-------	68	53	72	55	71	71	55	63	-------	56	59	56	-------	51	54
11	63	-------	69	54	72	55	70	71	55	64	-------	56	59	55	-------	50	53
12	64	-------	70	54	72	55	70	69	55	64	65	56	59	54	-------	50	-------
13	63	-------	70	54	72	55	70	72	55	62	64	56	59	55	-------	50	54
14	64	-------	69	-------	72	55	70	72	55	62	64	56	58	55	-------	50	55
15	64	-------	66	54	70	53	70	74	55	62	64	56	58	55	-------	49	54
16	64	-------	62	54	71	54	70	73	-------	62	64	56	57	56	-------	48	54
17	64	54	62	54	71	55	70	72	54	62	64	56	56	57	-------	48	54
18	63	53	62	54	71	55	70	72	55	62	60	56	56	56	-------	-------	54
19	62	54	64	54	70	55	70	72	54	64	60	57	56	55	-------	-------	54
20	60	53	66	55	70	55	69	72	55	64	59	-------	56	56	-------	49	51
21	57	53	68	55	71	55	69	72	55	65	59	57	-------	55	56	48	52
22	56	53	69	55	71	55	69	71	55	66	59	58	58	54	55	49	53
23	56	54	68	52	72	55	68	70	54	65	60	58	57	51	57	-------	52
24	60	54	68	53	72	55	69	70	55	65	60	57	55	50	57	49	51
25	62	55	69	54	72	54	69	70	56	63	61	57	53	48	57	46	-------
26	65	55	70	54	72	-------	68	70	56	62	62	58	51	-------	55	-------	-------
27	66	55	70	54	72	-------	66	68	56	61	62	58	54	-------	54	-------	-------
28	66	54	70	54	72	-------	66	67	56	62	62	59	56	-------	54	-------	-------
29	69	51	70	53	73	-------	66	66	55	62	62	57	56	-------	54	-------	-------
30	70	52	70	54	73	-------	64	65	55	63	61	57	56	-------	54	-------	-------
31	66	-------	-------	-------	73	-------	65	65	55	-------	-------	-------	56	-------	55	-------	-------
Average	62.5	53.6	66.9	53.9	70.9	54.8	69.5	70.8	55.0	63.5	62.3	56.4	57.1	55.7	55.5	50.5	53.6

materially in Sacramento River below the dam. In its natural state, Sacramento River displayed the great seasonal variations in flow so characteristic of all California streams. Practically all of the annual discharge flowed seaward in six months during the season of heavy rains and snow melt. Stream gaging at Kennett, now covered by the reservoir, from 1926 through part of 1942 recorded a maximum flow of 182,000 second-feet on February 28, 1940, and a minimum flow of 2,290 second-feet on October 4, 1934. At Red Bluff, California, about seventy miles below Shasta Dam, the maximum river flow during the period 1902-1942 was 291,000 second-feet on February 28, 1940; the minimum flow was 2,400 second-feet on August 13, 1931.

In comparison, a stream gaging station established at Keswick Dam showed a maximum discharge of 9,290 second-feet on August 1, 1945, and a minimum discharge of 1,720 second-feet on April 16, 1945, during the water year October, 1944, through September, 1945. Records taken at Red Bluff during the same year registered a maximum flow of 59,600 second-feet on February 1st, and a minimum of 2,620 second-feet on October 5th. The water year 1944-45 at Red Bluff was practically an average year. (All flow data from U. S. G. S. water supply papers).

Siltation

Many parts of the Sacramento River drainage are easily erodable. For numerous reasons, the Sacramento bears large quantities of silt and debris from its drainage whenever it is in flood. The reservoir above Shasta Dam acts as a settling basin which removes the silt load of the river and discharges nothing but clear water into the drainage below. Except for periods of flood run-off below the reservoir, the river is clear for more than ninety miles downstream. Return irrigation flows and gravel washing operations tend to muddy it in its lower reaches.

EFFECTS OF ECOLOGICAL CHANGES IN THE RIVER

The effects of the partially controlled ecological and limnological regime in Sacramento River below Shasta Dam are rather far-reaching. This study has by no means covered all of the facets involved in the altered environmental complex. However, an insured continuation of present conditions in Sacramento River will tend to improve that stream for the fresh water phase in the natural production of certain salmonoid fishes.

As is well known, the Sacramento-San Joaquin River System is the southernmost extension of the king salmon spawning range. It is generally accepted by students of population dynamics that survival on the fringes of the range of a well-established species is quite hazardous. Certain of these inherent problems affecting the life history and survival of king salmon in Central Valley have been, thus far, more or less ameliorated by the limnological changes in Sacramento River wrought by the operation of Shasta Reservoir.

Whereas water temperatures often regulated the presence or absence of salmon in certain sections of the river and also profoundly influenced the distributional pattern of the spring-run adult salmon summering in that stream, the present temperature conditions have afforded almost an optimum range. The thermal cycle in Sacramento River below Shasta

Dam now resembles cycles in streams which are in the center of the range of this species.

An additional effect of the changed thermal cycle in Sacramento River is the accelerated incubation of salmon eggs following deposition. The higher water temperature existing during November and December as a result of the stored heat in Shasta Reservoir has unquestionably accelerated the development of eggs and advanced the time of migration seaward (see Table 5). This change is a distinct advantage as far as the river life of the young salmon is concerned, because it affords a greater time for migration before dangers from irrigation diversions mount.

Extremes of flow definitely influenced the degree of success which spawning salmon achieved in Sacramento River prior to the construction of Shasta Dam. Before the dam was placed, salmon ascended to headwater streams to avoid floods. The streams above Shasta Dam lie in deep canyons and, except for their lower portions, do not present very good spawning riffles.

As a result of surveys conducted in 1939, biologists of the Fish and Wildlife Service concluded that approximately 40 percent of the spawning grounds available to salmon in Sacramento River would be eliminated by the construction of Shasta Dam (Hanson, Smith and Needham, 1940). More recent surveys of streams below Shasta Dam place the loss of spawning ground at nearer 50 percent. The surveys also demonstrated that about twenty-six thousand salmon nesting sites were in the main Sacramento below Shasta Dam in addition to those sites in permanent tributary streams such as Clear, Battle, Mill and Deer Creeks. Efficient use of the spawning area below Shasta Dam was not possible in most years before construction of the reservoir. Water temperatures and low flows usually inhibited extensive use of riffles downstream from Redding, California, by all but the late fall runs. Spring-run fish were restricted to the cooler waters of the upper reaches of McCloud and Sacramento Rivers by the high water temperatures below the mouth of Pit River.

There exists very little information concerning the number of trout, both resident rainbow and steelhead, which inhabited the Sacramento River below Redding prior to the construction of Shasta Dam. Since construction, however, there has been a great acceleration in the production of trout if relative fishing effort can be used as a measure. Many excellent trout catches are now made in the river almost anywhere in the 100-mile long river section below Shasta Dam.

Striped bass and shad were common in Sacramento River above Balls Ferry in 1943. In subsequent years they were less noticeable and at present few inhabit that area. Apparently, the waters in the river are too cold for these species. It has been observed repeatedly that some native fish species tended to forsake the Sacramento and crowd into warmer tributary streams. Introduced species such as bluegills, largemouth bass, green sunfish and catfish are less abundant in the upper river than they were before the dam was built.

One of the chief concerns during the investigative stage of the Shasta program was the safeguarding of spring-run salmon below the dam. This segment of the salmon population had suffered seriously because of the Anderson-Cottonwood Irrigation District Dam at Redding which had existed as a partial or almost complete barrier to their migration for ten years, 1917-1927, without a fish ladder (McGregor, 1922). A fish ladder

was installed in 1927 at the insistence of the State of California and the spring run increased following that year.

With Keswick Dam acting as a block, it was necessary to remove practically all of the spring salmon from the river in 1943 and 1944. In 1945, however, the spring-run salmon apparently lost their migratory urge when they reached the upper river. Water temperatures were ideal for holding and the salmon displayed no desire to migrate farther. Few were taken in the traps and it was believed, at first, that perhaps the spring run had diminished. But, observations on the spawning grounds disclosed an apparent increase over previous years. The spring run can be perpetuated in the river without difficulty as long as present conditions prevail. It is more likely to increase or at least maintain itself in the river than in either of the two places to which it was destined under the original plan.

POSSIBLE DANGERS TO SALMON DEPENDENT ON THE MAIN RIVER PLAN

The present operation of Shasta Reservoir is not typical of the ultimate operation schedule which will obtain once the Central Valley Project is completed. One of the primary purposes of the reservoir is to supply irrigation water to San Joaquin Valley farms by way of the Delta Cross Channel and the Delta-Mendota Canal. Neither of the latter units is completed and, consequently, demands on Shasta Reservoir for water are not at maximum level. Aside from power production, the reservoir is drawn upon only for sufficient water to insure the supply to Sacramento Valley farms, aid navigation, furnish minimum flows for fish and repel salinity in the Sacramento-San Joaquin Delta. A maximum demand of 4,600 second-feet will be added to the requirements from Shasta Reservoir once the Delta Cross Channel and Delta-Mendota Canal are in use.

When in full operation, Shasta Reservoir will fluctuate much more than it has to date. Recent operational studies for Shasta Reservoir involving many years of run-off and rainfall records and accurate knowledge of water release requirements show the frequency of recurrence of dead storage levels in the reservoir to be about six out of one hundred years. Minimum reservoir stages in the five worst years of record would be as follows:

October, 1924	815,000 acre-feet
November, 1931	710,000 acre-feet
November, 1932	1,107,000 acre-feet
November, 1933	909,000 acre-feet
October, 1934	500,000 acre-feet

Water temperatures in Shasta Lake as recorded by the Bureau of Reclamation indicate that even during years like 1934, Sacramento River temperatures could be held below 70 degrees F. by controlled releases of water at elevation 732, the lowest outlet in Shasta Dam.

The ecological situation favorable to salmonoid fishes which now exists in Sacramento River could be materially changed in periods of extended drought. Water temperatures in the river below the influence of releases from Shasta Dam would be high; how high is difficult to predict. Volumes of flow would be exceedingly small and the climatic characteristics of the area would exert a much greater influence on the river. During periods of such drought before Shasta Dam was built, salmon were

able to find satisfactory, although probably not fully adequate, conditions in headwater streams. Now, they would be forced to remain in the river below Keswick Dam and to depend almost entirely on the Bureau of Reclamation's operation schedules for survival.

The possibility of materially reducing, if not entirely eliminating, the salmon crop by using water required for its maintenance for other purposes is not as remote as might be supposed. Even under the present modified operation schedule of Shasta Reservoir, negotiations for adequate minimum flows in Sacramento River during January, February, March and April have been carried on with the Bureau of Reclamation in two of the four years of operation. The closest cooperation and actual demonstration of water requirements by means of joint inspections of spawning riffles at different known flow stages were required to justify a schedule of releases from Shasta Reservoir which provided no less than 2,500 second-feet of water below Keswick Dam. That minimum flow is undoubtedly the least amount of water which can be provided without seriously endangering a significant portion of the incubating salmon eggs and fry in Sacramento River gravels.

The possible transfer of salmon from Sacramento River to Coleman Hatchery on Battle Creek as a salvage measure during such drought periods would be quite unlikely. The hatchery would be filled beyond its capacity by a fraction of the total Sacramento River run and, besides, its capacity would have been already taken up with salmon in Battle Creek. Furthermore, it is very possible that waters of Battle Creek would be so warm that hatchery operations would be virtually impossible although no temperature records are available to support this statement. Even if water temperatures were satisfactory, the volume of flow in that stream would presumably be insufficient to satisfy existing water rights and to supply the hatchery with its normal water requirement of 50 second-feet. Battle Creek is said to have had a minimum flow of only 25 second-feet in 1924. Its minimum flow could not have been much greater in 1931.

SUMMARY

The construction of Shasta and Keswick Dams across the Sacramento River created a problem of salmon and trout maintenance in the river below Keswick Dam. This construction permanently removed from access approximately 50 percent of the natural spawning and nursery grounds available to these anadromous fishes.

A maintenance plan for this important fishery was selected from several plans presented by the Fish and Wildlife Service and the State of California after a two-year biological investigation of the problem.

The selected plan placed in operation on June 1, 1943, included the following essential features: (1) Transfer of spring-run salmon to Coleman Hatchery and to Deer Creek; (2) transfer of early fall run salmon to Coleman Hatchery; (3) holding of fall-run salmon in the Sacramento River between racks for natural spawning; (4) construction of: (a) Trapping facilities in Keswick Dam and Balls Ferry racks, (b) three racks in Sacramento River, (c) a rack in Deer Creek, (d) seven tank trucks for salmon transfer, (e) Coleman Hatchery on Battle Creek and appurtenances, and (f) a fish ladder around lower falls in Deer Creek.

Salmon actually counted at Balls Ferry rack or handled at Keswick Dam each year amount to: 41,364 in 1943; 69,481 in 1944; 44,652 in 1945;

and 9,927 in 1946. Estimates of the numbers of salmon in the maintenance area above Red Bluff, California, were: 144,000 in 1944; 106,000 in 1945; and 96,900 in 1946.

Natural spawning in Sacramento River was remarkably successful as is indicated by examinations of dead salmon and the hourly rate of catch in fyke nets of young salmon.

Spring-run salmon transferred to Deer Creek from 1941 through 1946 amounted to 15,972. Observable mortality among these fish was high at the start of operations but declined to almost nothing by 1946. Fyke net catches of seaward migrant salmon produced by these and native adult fish demonstrate successful spawning and egg incubation. The ultimate success of transfer of salmon to Deer Creek appears to be quite dubious.

As a result of reservoir operation, Sacramento River below Shasta Dam has become much cooler in summer and somewhat warmer in early winter. The run-off pattern of Sacramento River has been drastically altered.

The changed ecological complex in Sacramento River has had the following beneficial effects on salmon and trout production: (1) Water temperatures are at or near the optimum range; (2) higher river temperatures during late fall and early winter have accelerated development of salmon eggs and fry and increased the production of fish food; (3) more efficient production of young salmon has been made possible by the control of major floods; (4) the danger of silting has been ameliorated; (5) reduction of predator and competitor fish species has followed the lowering of river temperatures; (6) the survival and possible increase of spring-run salmon has been insured by the water temperature regime. Neither plan to relocate the spring run can be considered successful under present conditions; (7) with the exception of volume of flow, operation of Shasta Reservoir has created headwater conditions in Sacramento River for at least fifty miles downstream from Shasta Dam.

As nearly as can be determined, the average percentage of females spawned from lots of salmon transferred to Coleman Hatchery 1943-1945 inclusive, is 48.8 for spring run and 60.7 for fall run. The average mortality from the green-egg stage to the fry stage approximated 7.6 percent; that from the fry to fingerling (release) stage is about 2.7 percent.

None of the racks installed in Sacramento River as units of the main river plan functioned properly. They were not usable during the 1946 season.

Shasta Reservoir will fluctuate much more in the future than it has to date. An operational study made by the Bureau of Reclamation indicates that the reservoir will be drawn to dead storage level about six times in every 100 years. Under such drought conditions Sacramento River will be warmer, lower in flow, greatly influenced by air temperatures in Central Valley and subject to invasions of undesirable fish species. The possibility of using Coleman Hatchery as a salvage station in years of drought is very remote.

CONCLUSIONS

On the basis of operations to date and the meager positive evidence now available, it is concluded that: (1) Present ecological conditions

in Sacramento River below Shasta Dam are greatly improved for the natural production of salmonoid fishes. (2) The main river spawning plan is producing large numbers of seaward migrant salmon and presumably adult salmon in some measure of abundance. (3) The improvement in river conditions has compensated, as nearly as can be determined at present, for the loss of spawning grounds above Shasta Dam. (4) Racks in Sacramento River similar to those used are not satisfactory as means of blocking or controlling salmon migrations. (5) The main river has not been overcrowded with spawning salmon. (6) The numbers of salmon accommodated in the Shasta Salmon Maintenance Plan were far in excess of expectations. (7) The spring run of salmon is more likely to be perpetuated if left undisturbed in Sacramento River. (8) Ultimate success of the program depends on the maintenance of presently favorable river conditions. (9) Hatchery operations have been successful except for the problem of holding adult salmon, especially the spring run, until ready for spawning. (10) The Deer Creek program offers little hope of ultimate success without some changes in present conditions. (11) Experience has been insufficient to establish definitely the success or failure of the salmon maintenance work and observations and studies need to be continued. Criteria for Shasta Dam operation will change as new units for both control and storage of water in Sacramento River and the Sacramento Valley are built and integrated into the Central Valley Project. Constant evaluation of the effects on the fishery will be necessary as long as changing conditions may be anticipated.

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INTERSTATE WINTER DEER RANGE MANAGEMENT PLAN[1]

By Interstate Deer Herd Committee

(Editor's Note: The Interstate Deer Herd Committee was organized in May, 1945, to study the deer-livestock range problem on the winter range of the interstate deer herd. This committee is composed of representatives of the Oregon Game Commission, U. S. Forest Service, Regions V and VI, and the California Division of Fish and Game. As a result of their studies, the committee in October, 1947, agreed on a plan for management of the interstate winter deer range. This plan was revised somewhat in 1948. The revised plan is presented here for the first time.)

I. HISTORY OF AREA

A. Land Settlement

Historians have recorded that the northwestern portion of Modoc County was first entered by white men in the second and third decades of the Nineteenth Century. These were mainly Hudson Bay trappers in quest of furs. About 1850, Oregon-bound emigrants began passing through the country on the newly established South Road (Applegate Trail). These folks had many encounters with hostile Indians which discouraged settlement of the area.

Eastern Modoc County was settled in the sixties and western Siskiyou County somewhat earlier. The earliest record of a cattle outfit was the "D" Ranch, established in 1869 between Dorris and Mt. Dome. But it was not until after the Indians were subdued in 1873 that the pioneers felt free to expand into western Modoc County.

B. Early Livestock Use and Management

Earliest records of range use by cattle extend back to 1870. The Dorris and Churchill outfits, with base properties located west of Dorris, ranged cattle in the lava beds as far east as Dry Lake and Doublehead Mountain.

Stockmen at the time of settlement believed that the vast fields of bunch grasses were inexhaustible. Cattle were left out year-long, and as a result the ranges were heavily grazed and badly trampled during the wet portions of the year. Several severe winters taught the need for hay production and winter feeding. However, range use continued as early and as late as seasons would permit and as heavy as traffic would bear. There was no proper management.

The peak in cattle and horse use was probably reached prior to the 1896-1900 depression period. Even so, it has been estimated that in 1900 there were approximately 75,000 cattle and horses using the area bounded by Mt. Dome on the west, Goose Lake on the east, Mud Lake on the south and the state line on the north.

Sheep began using northwestern Modoc County in the eighties and numbers increased rapidly as the reputation of the area became known as a winter and lambing range.

[1] Submitted for publication January, 1949.

The peak in sheep use appears to have been reached between 1916 and 1920. It has been estimated that at that time approximately 125,000 sheep used the area between Mt. Dome and Doublehead Mountain for winter and spring grazing for the period November 1st to April 1st, with some use year-long.

In response to a petition to Congress from local residents, a proclamation by President Woodrow Wilson added 323,226 acres to the Modoc Forest on October 1, 1920 (See Figure 19). This area had been so badly abused by transient stock that the local livestock economy was jeopardized. In 1921, the first year of Forest Service administration, the local ranger was unable to cope with the 125,000 sheep that were crowding onto the ranges and called for assistance to remove the 60,000 head not covered by permit.

Cattle use for 1920 is more difficult to determine since they were uncontrolled and drifted at will. However, according to the best data available, an estimated fifteen thousand cattle were using the same area. Livestock numbers by decades are given in Table 1.

TABLE 1

Early Livestock Use on Winter Deer Range

Year	Cattle	Sheep
1910	Unknown	Unknown
1920*	15,000	65,000
1930	5,017	28,350
1940	4,134	19,530

* Estimated number for the Boles Meadow Allotment plus the 1920 addition. It is impossible to segregate use within the boundaries of the present winter deer range.

C. Early Game Use and Management

There is little historical data available which specifically refers to deer populations except in generalities. John Works in "An Expedition to Buenaventura" mentions scarcity of deer in 1823 in the area between what are now Canby and Adin. Fremont and Applegate reported an abundance of deer in 1846. Long established residents have stated that deer in Modoc County were plentiful in the 'eighties but after the hard winter of 1890 deer disappeared. Between 1915 and the early 'twenties deer were scarce and a man could ride all day without seeing an animal. Since that time deer have increased. A considerable number were lost during an outbreak of hoof rot in the area in the summer of 1923 and in several subsequent years. First observance of heavy cropping of juniper trees on the interstate winter deer range was in 1931. By 1935 heavy cropping of juniper was a cause of considerable concern.

A record of annual precipitation is given in Table 2 and is shown graphically in Figure 19.

TABLE 2

Annual Precipitation—Alturas and Cedarville—1945-1946

Year	Alturas	Cedarville	Average	Remarks
1895				
1896		9.29	9.29	
1897		22.68	22.68	
1898		13.19	13.19	
1899		8.90	8.90	
1900		17.87	17.87	
1901		12.60	12.60	
1902		14.43	14.43	
1903		12.91	12.91	
1904		12.39	12.39	
1905	16.14	18.13	17.13	
1906	9.89	9.46	9.67	
1907	17.65	17.46	17.55	
1908	18.37	18.07	18.22	
1909	6.79	9.65	8.22	
1910	14.61	21.69	18.15	
1911	14.16	11.42	12.79	
1912	10.13	11.47	10.80	
1913	11.03	10.18	10.60	
1914	16.77	15.23	16.00	
1915	8.88	10.80	9.84	
1916	9.98	9.67	9.82	
1917	15.22	11.91	13.56	
1918	11.33	10.58	10.95	
1919	9.81	10.73	10.27	
1920	11.83	10.49	11.16	
1921		12.93	12.93	
1922		10.26	10.26	
1923		10.09	10.09	
1924		10.02	10.02	
1925		9.19	9.19	
1926		11.82	11.82	
1927	9.39	9.45	9.42	
1928	13.58	12.59	13.08	
1929	8.26	8.36	8.31	
1930	8.23	11.27	9.75	
1931	10.25	10.58	10.41	
1932	8.78	12.43	10.61	Cold
1933	8.20	9.63	8.91	
1934	9.98	7.70	8.84	Cold
1935	12.55	10.18	11.36	
1936	12.22	10.09	11.15	
1937	12.87	12.34	12.60	
1938	18.44	18.48	18.46	
1939	12.76	14.79	13.77	
1940	8.57		8.57	
1941	15.58		15.58	
1942	15.01		15.01	
1943	14.05		14.05	
1944	12.28		12.28	
1945	11.46		11.46	
1946	16.61		16.61	
	8.84		8.84	

In California, prior to the placing of legal restrictions on hunting and bag limits, deer were taken for hides and meat by market hunters. This continued to 1901, at which time a restricted bag limit was effected. Table 3 shows the progression of game laws that were placed in effect in California beginning in 1852. This early legislation appears to have been largely intended to protect deer against promiscuous slaughter. The later laws, beginning in 1901, were designed to protect the doe herd. These laws applied particularly to the northwestern part of California in what is now known as District $1\frac{3}{4}$.

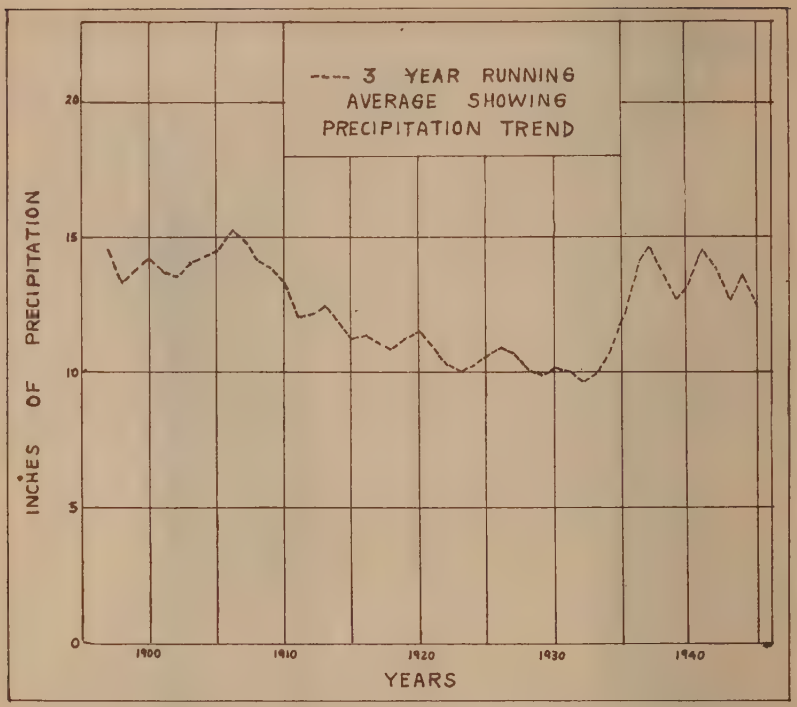

FIGURE 19. Trend of precipitation in Modoc County (adopted from "A land use study in eastern Modoc County," George A. Fischer, USFS, Region V, 1941

TABLE 3

Chronological History of California Game Laws

Year	Season	Limit	Spike Bucks	Forked-horn bucks	Hunting license	Deer tags	Remarks
1852-1882							Deer protected for 6 months each year.
1883-1892							Does and fawns protected.
1893-1894	Sept. 1-Oct. 15						
1895-1900	July 15-Oct. 15						
1901-1902	Aug. 1-Sept. 30	3 Bucks					Night hunting, sale of meat and hides prohibited.
1903-1904	July 15-Oct. 31	3 Bucks					
1905-1906	Aug. 1-Oct. 15	2 Bucks					
1907-1910	July 15-Sept. 30	2 Bucks			$1.00		
1911-1914	Aug. 15-Oct. 30	2 Bucks			1.00		
1915-1920	Aug. 14-Oct. 15	2 Bucks			1.00		Refuge 1B estab. 1917.
1921-1924	Sept. 1-Oct. 15	2 Bucks	Illegal		1.00		
1915-1926	Sept. 15-Oct. 15	2 Bucks	Illegal	Illegal	1.00		
1927-1934	Sept. 16-Oct. 15	1 Buck	Illegal	Illegal	2.00	$1.00	
1935-1936	Sept. 16-Oct. 15	1 Buck	Illegal	Legal	2.00	1.00	
1937-1945	Sept. 16-Oct. 15	1 Buck	Illegal	Illegal	2.00	1.00	
1946	Sept. 23-Oct. 21	1 Buck	Illegal	Illegal	2.00	1.00	
1947	Sept. 16-Oct. 15	1 Buck	Illegal	Illegal	2.00	1.00	
1948	Sept. 16-Oct. 15	1 Buck	Illegal	Illegal	3.00	1.00	Refuge 1B partially opened.

Table 4 shows the restrictions on deer hunting in Oregon beginning with 1901. It is not known whether any regulations such as those applied in California prior to 1900 existed in Oregon at the same time. In comparing this table with data in Table 3, it appears that in 1901, when California instituted the buck law, Oregon initiated a five-deer law, and 22 years later put a buck law into effect. The regulations outlined in Table 4 applied to that area in Lake and Klamath Counties inhabited by the interstate herd. A large portion of the Oregon summer range of the interstate deer herd was included in a game refuge. Recognizing a deer winter food problem, the Oregon Game Commission opened this refuge and authorized special seasons in 1939, 1941 and 1943 which resulted in the removal of approximately 4,775 antlerless deer from the interstate herd.

TABLE 4

Chronological History of Oregon Game Laws

Years	Bag limits	Seasons
1901-1912	5 deer	July 15-Oct. 31
1913-1916	3 deer	Aug. 15-Oct. 31
1917-1922	2 deer	Sept. 1-Oct. 31
1923-1929	2 bucks	Sept. 10-Oct. 20
1930-1939	2 Blacktail or 1 Mule Buck	Sept. 20-Oct. 25
1940-1946	1 buck	Sept. 25-Oct. 25
1947-1948	1 buck	Oct. 1-Oct. 20

Table 5 shown the deer kill on the winter range in California as tabulated from deer tag returns. Illegal kill and loss from crippling have not been taken into consideration in the preparation of this table. The agencies involved in the current studies will gather information on this subject whenever possible. Data is not available for kill on contributing summer range in Oregon and California.

TABLE 5

Reported Deer Kill on Winter Deer Range

Year	Interstate winter deer range	Hunters per deer killed (State average)	
		Hunters	Dee
1937	285		
1938	314	4	1
1939	386	3½	1
1940	589	3½	1
1941	240	4	1
1942	109	4½	1
1943	125	5⅛	1
1944	147	4⅝	1
1945		5⅜	1
1946	400	6	1
1947	279		

II. PRESENT SITUATION INTERSTATE DEER WINTER RANGE

A. Deer Winter Area

The Interstate winter deer range is considered as extending south from the California-Oregon state line to the vicinity of Badger Wells and thence northwesterly to Casuse Mountain (see Figure 20). It overlaps the winter range used by deer that summer south and west of this area.

FIGURE 20. Location of the summer and winter ranges of the Interstate Deer Herd

1. Associations

A classification by forage types indicates that there are four major range types within the boundary of the winter range, i.e., pine (includ-

ing bitterbrush), juniper, sagebrush and grassland. These types may be grouped into four associations, comprising 512 square miles (327,700 acres), as follows:

a. Associations of Ponderosa pine, bitterbrush and grasses (55 square miles). This association is used by cattle and sheep through the summer but is normally used only lightly by migrating deer as the elevation is too high for winter use during normal years.

b. Association of juniper, bitterbrush, sagebrush and grasses (187 square miles). This association extends in a belt from Crowder Flat to Timber Mountain. Although the elevation is lower than the pine type, most of the deer normally leave this area by January 15th.

c. Association of juniper, sagebrush and grass (130 square miles). This association includes the lower elevations and is of greatest value to the deer herds because in the event of a severe winter they are forced to concentrate and subsist on the margin of forage available on this type of range. A combination of heavy dual use, range fires, climatic extremes and other factors have resulted in the elimination of a large part of the bitterbrush and sagebrush on this range and over 60 percent of a dense stand of juniper has been skirted. This area contains the most depleted portions of the winter range.

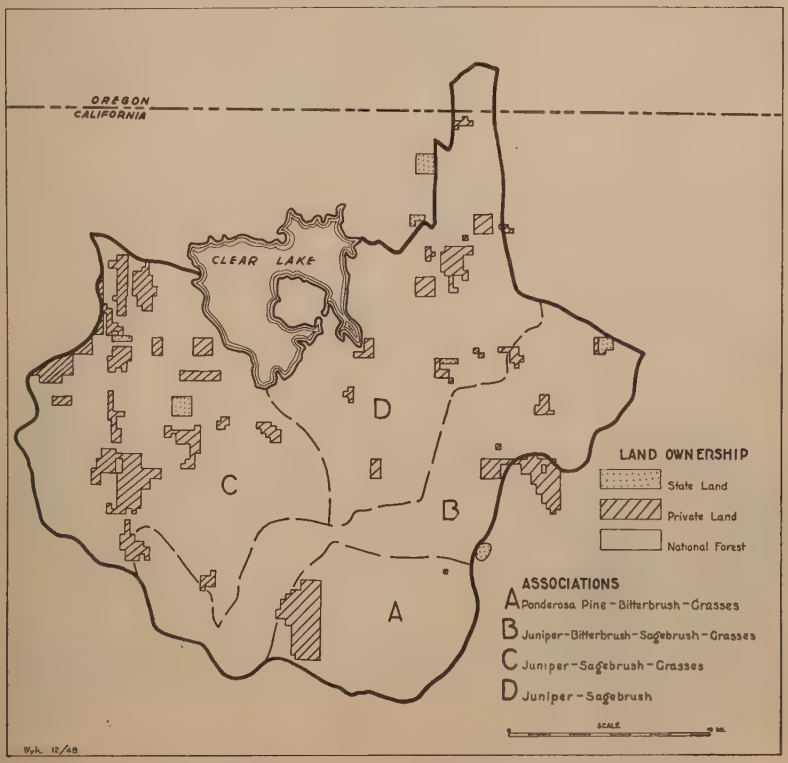

FIGURE 21. Principal associations of forage types and land ownership on the interstate winter deer range

d. Association of juniper and sagebrush (140 square miles). This association includes marginal range lands east of Clear Lake which are used heavily by livestock but are only used by deer during the northward migration in the spring.

Figure 21 shows the location of these four vegetation type associations.

2. Key Forage Species

An inventory of the available forage on the winter range of the Interstate Deer Herd reveals that at the present time perennial vegetation covers 21 percent and annual vegetation 9 percent of the ground surface. A breakdown into principal forage species is given in Table 6.

TABLE 6

Principal Forage Species on Winter Range

Common name	Scientific name	Average percentage ground surface covered
	Shrubs and Trees	
Sagebrush	*Artemisia* spp.	7.8
Bitterbrush	*Purshia tridentata*	1.3
Rabbitbrush	*Chrysothamnus* spp.	1.1
Juniper (understory)	*Juniperus californica*	0.3
Mahogany (understory)	*Cercocarpus ledifolius*	0.04
Squaw carpet	*Ceanothus prostratus*	0.7
Phlox	*Phlox* spp.	0.1
	Perennial Forbs	
Balsam root	*Balsamorhiza sagittata*	0.5
	Perennial Grasses	
Bluegrass	*Poa* spp.	2.9
Squirrel tail	*Sitanion hystrix*	1.2
Needlegrass	*Stipa* spp.	1.0
Idaho fescue	*Festuca idahoensis*	0.5
Wheat grass	*Agropyron spicatum*	0.5
Dryland sedge	*Carex* spp.	0.9
Other perennials		2.5
All perennials		21.3
	Annuals	
Downy chess	*Bromus tectorum*	3.7
Forbs		5.4
All annuals		9.1

Recognizing that the wintering deer herd will be forced to subsist on the available browse forage in the event of a severe winter when herbs and grasses are covered by snow, and that bitterbrush is preferred by both deer and livestock, this shrub is considered the key shrub species for both deer and livestock where it occurs in practical densities. In juniper areas where bitterbrush is not present, understory juniper is considered the key browse species for deer.

Bluegrass *(Poa secunda* and *nevadensis)* is considered the key grass species for deer. Squirrel tail *(Sitanion)* on the grass type, bluegrass on the pine type, and Idaho fescue *(Festuca idahoensis)* on the sage and juniper type are the key grass species for livestock.

3. Studies

a. Deer Stomach Analysis. An analysis of the stomach contents (Interstate Deer Herd Committee, 1947) of 53 deer taken during the period from November, 1946, through March, 1947, indicated that deer then selected food in the following proportions:

Dry grasses	31.1 percent	Juniper	9.4 percent
Green grasses	4.5 percent	Mahogany	3.6 percent
Forbs	11.0 percent	Manzanita	.2 percent
Sagebrush	19.4 percent	Other browse	5.3 percent
Bitterbrush	14.8 percent	Lichens	.7 percent

b. Forage Utilization Checks. Sixty percent of the annual growth has been determined to be the maximum use to which bitterbrush can be subjected and still maintain its vigor and be able to reproduce. Studies were made in the grazing years of 1943-44, 1945-46 and 1946-47 to determine the percentage cropping by both livestock and deer. All of the studies indicated more than 60 percent use of this key species.

The 1947-48 growing season was good and forage yield was considered well above normal. A utilization check made on all perennial forage plants present on 200 sample plots indicated that cropping of both bitterbrush and other key forage species was within allowable limits. The census data indicate that deer numbers have declined. Livestock use has also declined. Further forage studies will show whether the range improves under the degree of use now prevailing.

c. Grazing Load. Grazing use by livestock permitted on the winter range during the 1946 and 1947 grazing seasons is shown in Table 7. Location of the livestock grazing allotments is shown in Figure 21.

TABLE 7

Number of Livestock Permitted on the Winter Range

Grazing allotment	Percent within winter deer range boundary	Actual use (AUM's)* 1946 Cattle	1946 Sheep	1947 Cattle	1947 Sheep	Number permittees	Season
Clear Lake Spring	100.0	1,335	5,660	2,395	3,187	12	†4/16-5/31 ‡4/ 1-5/31
Casuse	100.0	----------	500	----------	501	1	4/ 1-5/31
Hackamore	47.6	----------	476	----------	386	(1)	6/ 1-9/30
Hog Lake	27.4	----------	110	----------	110	1	6/ 1-9/30
Lava Bed Winter	14.9	----------	373	----------	290	(4)	12/16-2/28
North Badger	100.0	----------	900	----------	741	(1)	6/ 1-9/30
South Badger	100.0	----------	1,000	----------	721	(1)	6/ 1-9/30
Boles	46.6	4,544	----------	4,320	----------	3 (1)	5/ 1-9/30
Dry Lake	82.4	1,018	----------	1,457	----------	2 (1)	4/16-9/30
Howard's Gulch	11.7	406	----------	297	----------	3	5/ 1-9/30
Mowitz	100.0	1,750	----------	1,550	----------	(1)	5/ 1-9/30
Potter Pasture	100.0	00	----------	1,584	----------	2	6/ 1-9/30
Totals	----------	9,053	9,019	11,603	5,936	24	----------
Grand total	----------		18,072		17,539		

* Sheep months converted to animal unit months by a ratio of 5 to 1. Figures include private land permits, free use and trespass.
† Cattle.
‡ Sheep.

Grazing use by deer that wintered on the range, as determined by car strip census, is given in Table 8. During the winter of 1947-48, deer were on the Modoc winter range for 6.5 months, October 25th to May 10th.

FIGURE 22. Location of livestock grazing allotments on the interstate winter deer range

TABLE 8

Number of Deer on the Winter Range

Year	Number	Months upon winter range	*AUM's
1946-47	12,400	5.7	17,670
1947-48	9,800	6.5	15,925

* Deer months converted to animal unit months by a ratio of 4 to 1.

B. Composition of Deer Herd

Table 9 gives the composition of the deer herd using the critical Modoc winter range. The composition percentages are based on classification of 1,736 deer.

TABLE 9

Deer Herd Composition

Bucks		Does		Fawns		Total	
Number	Percent	Number	Percent	Number	Percent	Number	Percent
784	8	5,782	59	3,234	33	9,800	100

C. Comparative Values of Livestock and Deer

It is not possible to assign monetary values to the recreational benefits of deer hunting in health, peace of mind, and as an opportunity for development and training of the youth of America.

It is recognized that livestock production is an important industry in Modoc County. It is also recognized that the deer herds are an important asset to the people of both California and Oregon and that the numbers of deer that can be maintained on over one thousand sections of available summer range in Oregon and California is largely dependent on the quantity of forage available upon the 200 sections of range where the deer herds concentrate during the critical months of February and March.

III. ACTION PLAN

A. Objectives

1. The first objective in management of the winter range is to determine the productive capacity for grazing and browsing animals of this public range already depleted by past abuse. The range is used by sheep in the spring and summer, cattle during the spring, summer and fall, and by a migratory deer herd during the winter season.

2. The second objective is to balance the combined range use by livestock and deer with the average forage production of the range.

B. Policies

1. The allowable crop of key forage species on the winter range will, for the next three-year period, be allotted to deer and livestock on a 50/50 basis.

2. A system of forage utilization check plots has been established on the winter range. The plots are examined jointly at the proper times by members of all the agencies concerned with administration of the deer herd and/or its range. Utilization data based on these examinations will be accepted by the agencies as a true index of the forage use on the winter range.

3. Adjustments in numbers of livestock and/or deer will be based on need and will be made on the basis of three-year averages. The first three-year period started with the forage year 1947. Necessary adjustments in deer numbers will be accomplished by the removal of antlerless deer on the winter range during the period of use.

4. The best principles of livestock range management will be applied to the area. These will include proper distribution, salting, deferred and

rotation grazing, and proper stocking based on allowable use of forage and range readiness. Water developments will be installed as circumstances permit.

The best principles of deer range management will be applied to the area. These will include:

a. Proper stocking based on allowable use of forage and maintenance of a satisfactory herd composition through hunting, trapping, transplanting and the opening and closing of refuges.
b. The control of distribution through salting, coppicing and fertilizers.

5. Habitat improvement for both deer and livestock through reseeding, water developments, coppicing and various other techniques, will be made as conditions allow.

C. Maintenance of the Plan

1. A record of permitted and actual use, and season of use, by livestock on allotments in the winter range, will be kept concurrently by the Forest Service and made available to the other agencies.

2. A car strip census to determine herd composition will be made each December jointly by the Modoc National Forest, California Division of Fish and Game and Oregon Game Commission.

3. A car strip census will be made each January jointly by the agencies to estimate the number of deer on the winter range.

4. A pellet group census will be made jointly each spring by the agencies to determine intensity of deer use by types and areas.

5. During the spring migration of deer to their summer range, a track count will be made by the Oregon Game Commission and the California Division of Fish and Game, at the state line.

6. Airplane reconnaissance will be made as needed by the California Division of Fish and Game to help in location of deer prior to census and track counts.

7. A system of forage utilization check plots has been established. These plots will check utilization of forage by livestock and by deer and will sample key species on the winter range. Checks will be made jointly by the agencies at the time livestock leave the range in the fall and at the time deer leave the range in the spring and at such other times as may be necessary.

8. Photographic records of forage use and condition on the winter range will be continued, systematized and supplemented.

9. The study of forage preferences by deer through stomach analysis, or other means, will continue as conditions permit.

REFERENCE

Interstate Deer Herd Committee
1947 Second progress report on the cooperative study of the interstate deer herd and its range. Calif. Fish and Game, Vol. 33, pp. 287-314.

THIRD PROGRESS REPORT ON THE COOPERATIVE STUDY OF THE INTERSTATE DEER HERD AND ITS RANGE[1]

By Interstate Deer Herd Committee

INTRODUCTION

A cooperative study of the interstate deer herd and its range was inaugurated in the fall of 1945. Representatives of the Oregon Game Commission, the United States Forest Service, Regions V and VI, and the California Division of Fish and Game are participating in this study. An initial progress report on preliminary phases of the study (Interstate Deer Herd Committee, 1946) and a second progress report (Interstate Deer Herd Committee, 1947) have been published. The second report presented information on the range and on livestock numbers which will not be repeated here.

The following report is a compilation of several individual papers presented by various field workers at the fall meeting of the committee. Personnel of the cooperating agencies which were primarily responsible for the field work reported here are: George L. Burnett, Fred Alberico, and George A. Fischer, Modoc National Forest; William Lightfoot, Winfred V. Mason, Austin E. Hamer, Paul Bond, and Robert U. Mace, Oregon Game Commission; James D. Stokes, Gordon Bolander, Nathan L. Rogan and William P. Dasmann, California Division of Fish and Game; and Randal McCain, University of California.

CAR STRIP CENSUS

The same strips and strip widths were used in 1947-48 as were used in 1946-47 (Figure 22). A December and a January count were made as proposed in the Interstate Winter Deer Range Management Plan. (Interstate Deer Herd Committee, 1949). Additional data on herd composition secured during November have been incorporated with the regular strip census counts. Data on herd composition were assembled on each count by representatives of the three participating agencies. An effort was made to count only on clear sunny days so that the maximum number of deer could be counted. Even so, some counting took place on overcast days during the December count. It was generally clear during the January count.

The weather was very open during both December and January. There was never enough snow to really concentrate the deer. At the time of both counts deer were numerous outside the recognized winter concentration area. The counting crew felt that the count was low for that reason.

[1] Submitted for publication January, 1949.

A compilation of the census data is presented in Tables 1 to 5.

FIGURE 23. Location of car strip counting units

TABLE 1

Deer Population in the Principal Counting Units—1947-48

	December	January
Blue Mountain—Boles	675	1,682
Badger Pine	867	1,282
Bitterbrush—Transition	3,556	4,164
Juniper Annual Grass	2,806	2,406
Open Juniper Sage	386	241
Total	8,290	9,775

TABLE 2

Total Number of Deer in Glass Mountain Herd—1947-48

	December	January
Glass Mountain	2,252	2,680

TABLE 3

Interstate Deer Herd—Herd Composition for Past Five Years of Study

	1943-44		1944-45		1945-46		1946-47		1947-48	
	Number	Percent of herd	Number	Percent of herd	Number	Percent of herd	Number	Percent of herd	Number	Percent of herd
Bucks	1,548	8.6	1,440	8.0	870	6.4	1,116	9.0	792	8.1
Does	13,376	63.2	9,900	55.0	8,215	60.4	7,068	57.0	5,767	59.0
Fawns	5,076	28.2	6,660	37.0	4,515	33.2	4,216	34.0	3,216	32.9
Totals	18,000	100.0	18,000	100.0	13,600	100.0	12,400	100.0	9,775	100.0

TABLE 4

Interstate Deer Herd—Buck Trend by Antler Point Classes

Points	1943-44		1944-45		1945-46		1946-47		1947-48	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent	Number	Percent
1	77	5	130	9	70	8	112	90	151	19.0
2	465	30	403	28	226	26	279	25	321	40.5
3	465	30	360	25	226	26	245	22	131	16.6
4	433	28	489	34	331	38	335	30	146	18.4
4+	108	7	58	4	17	2	145	13	43	5.5
Totals	1,548	100	1,440	100	870	100	1,116	100	792	100

TABLE 5

Buck-Doe and Doe-Fawn Ratios by Census Years—Interstate Herd

Year	Buck-doe ratio	Doe-fawn ratio	Number deer classified
1937-38	1:5.6	1:0.81	1,262
1938-39	1:3.5	1:1.25	2,882
1939-40	1:4.9	1:1.03	1,338
1943-44	1:7.4	1:0.45	5,986
1944-45	1:6.6	1:0.67	3,007
1945-46	1:9.5	1:0.54	1,696
1946-47	1:6.2	1:0.61	1,603
1947-48	1:7.3	1:0.56	1,736

Glass Mountain Herd

1944-45	1:3.8	1:0.71	432
1945-46	1:3.9	1:0.65	587
1946-47	1:4.0	1:0.60	437
1947-48	1:6.1	1:0.69	748

STATE LINE TRACK COUNT

The 1948 spring migration track count along the California-Oregon state line was conducted between April 15th and May 25th. The counting area extended from a holding corral located approximately two miles east of Willow Reservoir to Young Valley, a distance of about twenty miles. This area was more extensive than that tabulated in 1947 when a nine-mile strip was counted.

Adverse weather conditions seriously hampered activities. Snow, sleet or rainstorms occurred daily during the counting period. This not only caused extreme fluctuations in the progress of the migration but also obliterated many tracks of the migrating deer. The peak of the movement occurred much later than the previous year.

The methods employed were similar to those employed the previous year. Saddle horses were used to pull a brush drag over the counting strip. The purpose of this dragging was to obliterate old tracks and prepare a bed for the next day's observations. Wet conditions made this task difficult and no dust mulch was formed as in 1947.

Figure 24 shows indicated numbers of northward migrants by strip units. Figure 25 shows the total numbers by daily intervals. Observations following periods in which weather conditions prevented field work include all deer crossing since the previous count and not a single day's total.

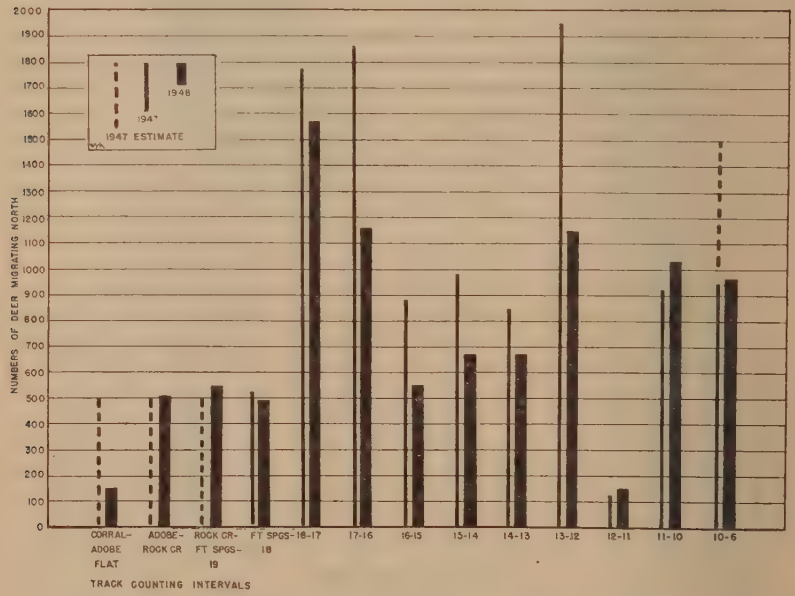

FIGURE 24. Numbers of deer migrating north between track counting intervals—Holding Corral to Mile Post 6

Counts were made each day that the weather permitted. Mile posts were used to mark the strip units where these occurred; otherwise natural landmarks served for this purpose (see Figure 26). The southbound deer were subtracted from the northbound deer to determine the size of the herd.

A recapitulation of total northward migrants by strip units is shown in Table 6. Number of migrating deer by days is shown in Table 7.

DEER PELLET GROUP COUNT—SPRING, 1948

Procedure

The 1948 deer pellet count used methods similar to those used the previous year. (See also McCain, 1948). However, in order to allow the

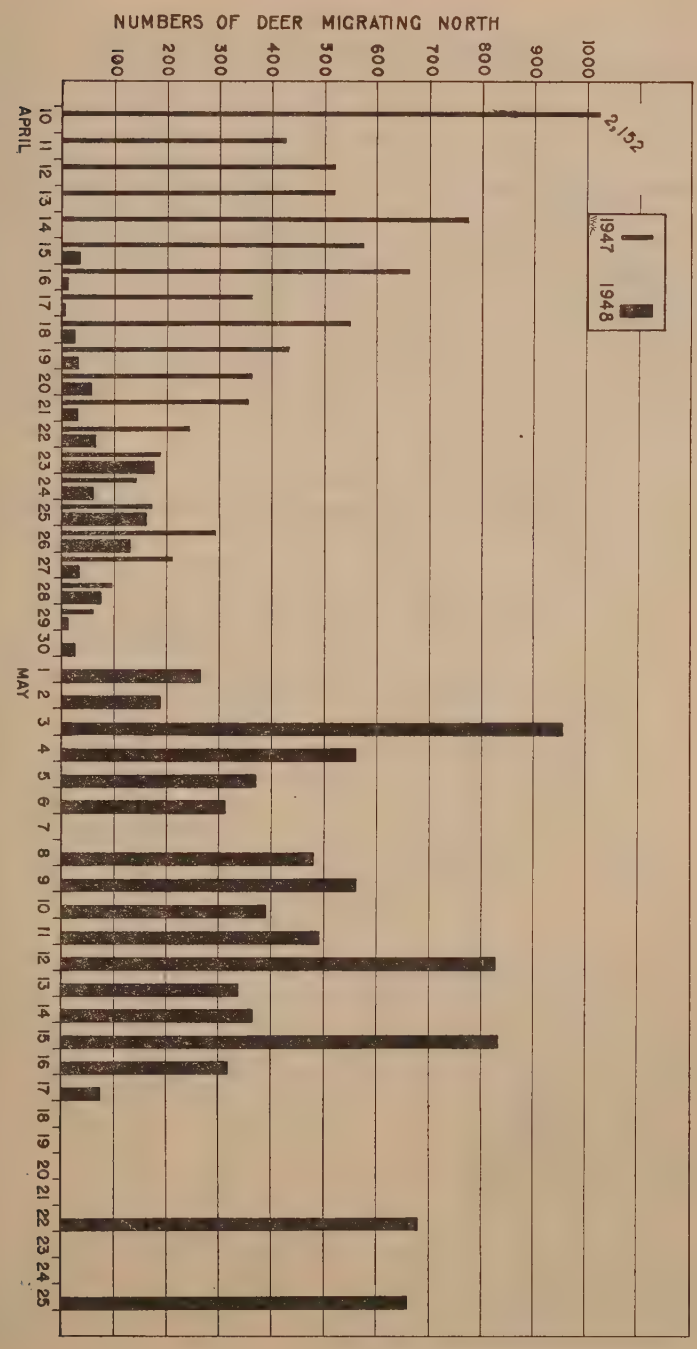

FIGURE 25. Numbers of deer migrating north by days between Holding Corral and Mile Post 6

TABLE 6

Stateline Track Count by Units—1947-1948

Area	Count		Estimate		Total	
	1947	1948	1947	1948	1947	1948
Willow Reservoir to Adobe (6 miles)			500		500	
Corral to Adobe (3 miles)		140				140
Adobe Flat to Fort Spring		1,058	1,000		1,000	1,058
Fort Spring (M.P. 19) to M.P. 18	528	498			528	498
M.P. 18 to M.P. 17	1,773	1,570			1,773	1,570
M.P. 17 to M.P. 16	1,864	1,166			1,864	1,166
M.P. 16 to M.P. 15	881	558			881	558
M.P. 15 to M.P. 14	984	677			984	677
M.P. 14 to M.P. 13	849	677			849	677
M.P. 13 to M.P. 12	1,954	1,142			1,954	1,142
M.P. 12 to M.P. 11	122	144			122	144
M.P. 11 to M.P. 10	929	1,025			929	1,025
M.P. 10 to M.P. 6	942	974	558		1,500	974
M.P. 6 to Goose Lake			1,000		1,000	
Totals	10,826	9,665	3,058		13,884	9,665

TABLE 7

Stateline Track Count by Days—1947-1948

Day	Count	
	1947	1948
April 10	2,152	
11	414	
12	812	
13	511	
14	872	
15	588	36
16	788	19
17	412	10
18	577	29
19	540	32
20	403	53
21	393	35
22	244	64
23	187	172
24	149	59
25	172	162
26	299	133
27	212	27
28	98	79
29	61	12
30		21
May 1		270
2		188
3		960
4		566
5		369
6		308
8		476
9		562
10		392
11		486
12		830
13		342
14		368
15		878
16		320
17		78
22		676
25		653
Totals	9,884	9,665
	*942	
	10,826	

* Tracks counted between mile post 10 and mile post 6 on April 22.

counts to be taken at the new forage utilization check plots, an entirely new set of sample plots were used. A one-tenth acre sample was obtained at each forage plot by counting all groups of deer pellets on a six-foot strip eleven chains long. This eleven-chain strip extended along the 200-foot transect line, then offset 45 feet to each side, and returned in two strips parallel to the base line.

The pattern of deer use indicated by the 1948 count was similar to that of 1947. The differences may be due as much to inadequate sampling as to an actual shift in deer use. Both seasons were open and relatively free of snow. Figure 26 shows where the deer use occurred but does not indicate when it occurred. It would be possible by making repeated pellet counts to map the progress of deer movements, but for the purpose of determining deer population a single count at the end of the season is all that is needed.

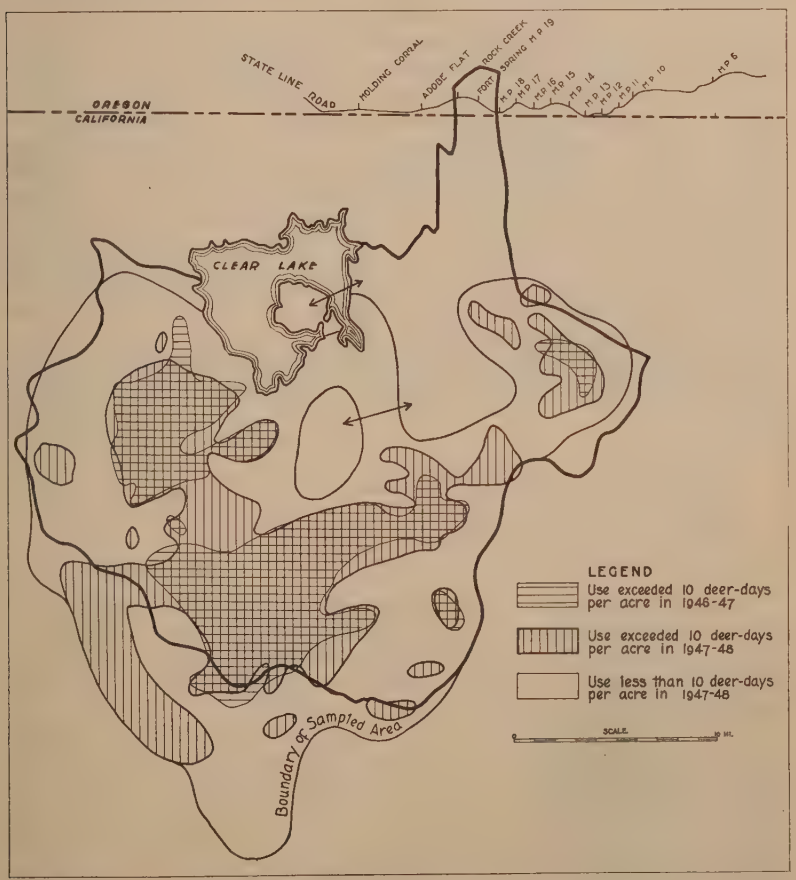

FIGURE 26. Intensity of deer use as shown by pellet group counts on main part of range. Heavy boundary line is the boundary of the Interstate winter deer range. Light boundary line is boundary of the area sampled. Also shows location of track counting strips along state line.

When it is desired to compute a deer population from pellet counts, the time element should be determined as precisely as possible. The date when the deer herd started using the winter range in the fall of 1947 has been estimated at October 25th. It is believed that by November 1st, at least half of the deer were on the winter range. The date when the herd left the winter range in the spring of 1948 has been established by the state line track counts. May 10th has been used as the average departure date. This makes an over-winter period of 192 days, 20 days longer than last year.

Computed Deer Population

The compiled data obtained from the pellet count may be summarized as in Table 8. A conversion ratio of 12.7 pellet groups to one deer day was used in the compilation.

TABLE 8

Summary of Deer Pellet Count Data

Area	Size in acres	Indicated deer use	Number sample plots	Average deer days/acre	Total deer days by area
1	110,000	Over 10 days/acre	87	21.2	2,332,000
2	115,000	Less than 10 days/acre	101	3.3	379,500
3	100,000	2 days/acre (estimated)	estimate only	(est.) 2.0	200,000
Total	325,000		188		2,911,500

When the total of 2,911,500 deer days is divided by 192 days (the average length of stay), a total population of 15,200 deer is obtained. It is pointed out that an error of one day in the length of stay adds or subtracts only 53 deer from the total.

Analysis of the pellet count data indicated that the average number of deer days per acre in each of the four main vegetation types was as follows:

Type	*Deer days/acre*	*No. of plots*
Grass	4	48
Sagebrush	10	45
Pine	12	46
Juniper	21	49
All	12 (average)	188

Because of the necessity of estimating the number of deer days per acre on the 100,000 acres not sampled, a possibility of error exists. It is common knowledge, however, that the unsampled area receives the least amount of deer use, and it is improbable that a survey of this area would result in a significant change in the final figure.

The computed figure of 15,200 deer includes all the animals that winter in the area surveyed. This area (see Figure 25) extends beyond the recognized boundaries of the Interstate deer herd winter range. The population figure includes California deer that migrate into the winter range from the south and west and from other nearby areas, plus those that spend the entire year within the boundaries used.

Key Areas

The deer pellet count may also be used to determine key areas on the winter range if key areas be defined as those areas which furnish the bulk of the winter forage. The amount of dung on the ground is in direct proportion to the volume of forage removed by the deer. The areas may be located merely by outlining the plots that show the highest counts.

If a proper balance of use against forage production is maintained within the key areas, the remainder of the range should be automatically safeguarded. Once key areas are determined on the ground, the job of sampling can be confined mainly to such areas.

FORAGE UTILIZATION CHECK

Introduction

In October, 1947, a plan was adopted by the agencies concerned for the management of the Interstate Winter Deer Range (Interstate Deer Herd Committee, 1949). The objective in management of this area was stated to be the balancing of combined range use by grazing and browsing animals with the average forage production of the range. Within this limit the plan provided that the range forage crop produced by key plant species would be divided between deer and livestock on a 50/50 basis. The plan provided for establishment of a system of forage utilization check plots from which to obtain data on the degree of cropping by deer and by livestock. It was agreed that each of the agencies would provide men to participate in the spring and fall utilization checks. The agencies agreed to accept the utilization check data as a true index of forage use on the winter deer range.

The Method

During October, 1947, a series of 200 forage utilization check plots were established on the winter range (see Figure 27). These plots were divided among the four principal range types, viz., sagebrush, juniper, pine and grass.

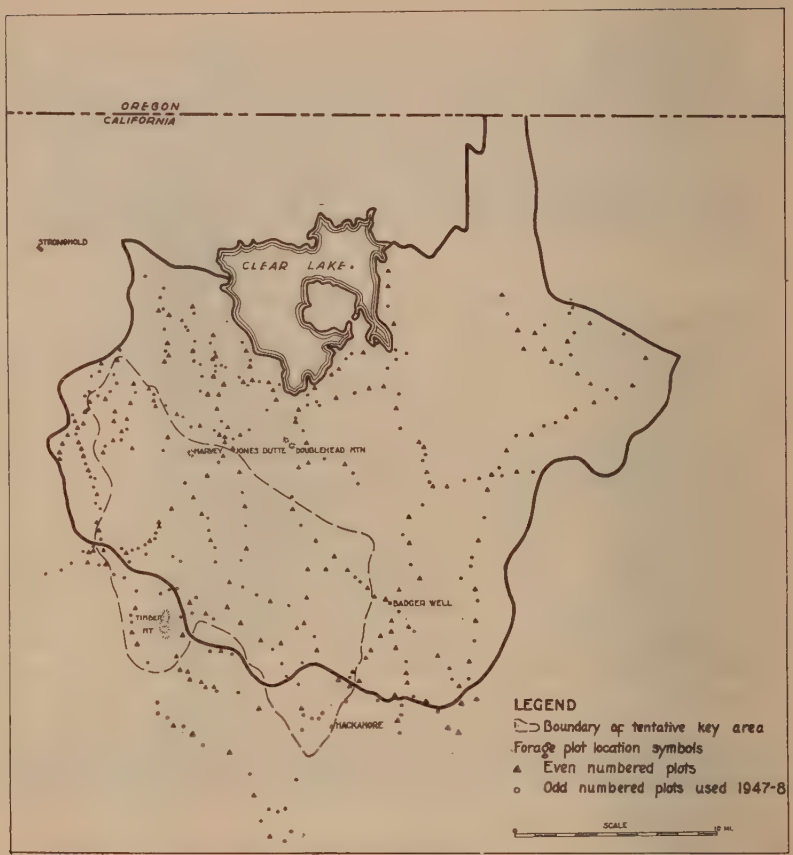

FIGURE 27. Distribution of forage utilization check plots. Odd numbered plots were used during the 1947-48 season. Location of tentative key area is shown by broken line.

Plots were established at predetermined intervals along, but at right angles to, the many roads and trails that traverse the winter range. Plots consisted of line transects 200 feet long. Plant measurements and estimates of cropping were taken along 500 inches of this line. The 500 measurement inches were broken into 20 segments, each 25 inches long. These segments were spaced along the transect line at 10-foot intervals.

Measurements were limited to 500 inches of the transect lines in order to keep the job of checking individual plots within reasonable time limits. The 500-inch length is also convenient in that density data can be converted to percentages by multiplying by two and marking off one place. The 500-inch total was divided into twenty 25-inch segments spaced along a 200-foot line in order to get more representative samples less influenced by spot differences in site and use. Because the plots are to be checked for a number of years, the individual segments were marked

by painted iron spikes driven into the ground. The transects were marked at the roadsides with numbered iron posts.

The plots were designed to give information on: (1) Percentage cropping by livestock and by deer of certain species of plants; (2) the relative yield of the various plant species; and (3) the composition of the ground cover.

Data on ground cover composition are valuable not only as an indicator of conditions on the range at the present time but also as a base from which to measure trends. By remeasuring the plots at three five-year intervals and comparing the latest data with the base data, changes in density and composition can be determined. Such changes should indicate whether the range is getting worse or better.

In measuring relative yield and composition of ground cover, a record was made to the closest inch of the amounts of bare soil, rocks, litter, moss, dead shrubs and living individual plants that were cut by the 25-inch segments. The actual diameters of the plants were not considered; only the number of inches along the line covered by the foliage in normal density was recorded.

The plants cut by the 25-inch segments also were used as samples from which to determine percentage cropping. However, estimates of the amount of forage cropped from these plants were based not on the amount of foliage cut by the transect line but upon the amount taken from the entire plant. Estimation of the amount of leafage cropped from grasses was made by a height-weight method similar to that described by Lommasson and Jensen (1942). Percentage cropping of forbs was estimated as indicated by the amount of volume removed. The percentage of total inches of new growth taken from shrubs was estimated by the visual estimate method described by Hormay (1943). The percentage cropping of total inches of available terminal twigs of juniper forage was determined by a twig measurement method similar to that described by Aldous (1945). Metal tags were placed on four available terminal twigs on each tree and the length of the twigs in inches before and after the season of use was recorded.

In compiling average use from the data so obtained, percentage cropping of each plant was weighted with the number of inches of its leafage that covered the segment line which is indicative of yield. Smaller, less productive plants were thus given a lesser weight in the final averages than those larger and more productive.

Cover Composition on Winter Range

Compilation of data from 200 plots indicates that on the average 69.6 percent of the ground surface of the winter range is not covered by forage. On the average 9.1 percent of the winter range is covered by annual vegetation. Perennial grasses, forbs and shrubs, cover 21.3 percent of the ground surface on the average area. The composition of the ground cover is shown by types in Table 9.

TABLE 9

Composition of Ground Cover on Winter Range

Range type	Percentage of ground covered		
	Not covered by forage	By annual forage	By perennial forage
Grass	63.8	25.6	10.6
Pine	77.1	1.4	21.5
Juniper	70.5	6.8	22.7
Sage	67.0	2.5	30.5
All types	69.6	9.1	21.3

It should be pointed out that on the pine and juniper types there is, in addition to the cover indicated above, an overstory of trees in various densities. No attempt was made to measure the percentage of the ground surface covered by this overstory.

Factors Affecting the Utilization Check

Because livestock graze the Interstate Winter Deer Range from April 5th to October 15th, while deer come to winter on the area from approximately October 15th to April 15th, it is possible to separate percentage cropping by livestock from that by deer. The forage utilization check made in late October, 1947, is indicative of the amount of forage taken by livestock. The check made in April, 1948, is indicative of the amount of forage taken by deer.

The fall check does not give data directly indicative of livestock use of grass or forbs. Generally, some of the forbs and most of the perennial grasses, especially the blue grasses (*Poa secunda* and *nevadensis*), have started growth before the deer leave the range in April. This green growth is cropped by deer. Hence the percentage cropping of grasses and forbs indicated by the fall check includes the amount taken by deer in the spring. This must be subtracted from the fall data to determine percentage cropping by livestock alone. The spring check does not give data directly indicative of deer use of shrubs. The spring data include the amount taken by livestock during the previous grazing season. This must be subtracted in order to determine the amount taken by deer.

A deer stomach analysis study made in 1946-47 (Interstate Deer Herd Committee, 1947) indicated that deer consumed considerable dry grass and some dry forb leafage during their stay on the winter range. The spring check data do not include this cropping. They indicate the percentage cropping of available green grass and forbs only. Because cured grasses and forbs undergo a breakdown from weathering during the winter months, and because any estimate on cropping of stubble would reflect this deterioration, no attempt was made to determine the amount of cured grass or forbs taken by deer during the winter months.

McCarthy and Price (1942) concluded from an intensive study of grass growth and vigor under various seasons and degrees of cropping, that the critical periods in the life cycles of the grass plants studied were: (1) From flower stalk formation to and including ripe seed; and (2) during the forepart of the normal carbohydrate storage period. They

stated that close harvesting during these periods injures the plants. They pointed out that early grazing when plants are four to six inches high, providing it is not too frequent, and grazing in the fall period when herbage is dry or drying appear to be the safer periods of use.

Deer crop the young grass plants as soon as there is sufficient growth to nibble and before the plants are four to six inches high. But the average percentage cropping is low and it has not been determined on the winter range whether this light use causes significant damage to the grass cover. When deer return to the range in the fall, grass leafage has cured. Cropping of this cured leafage by deer, so long as it is not generally so close as to remove that part of the stubble needed to protect green growth from frost and so long as it does not result in a significant reduction in litter, should not cause range damage.

The data on ground cover composition already presented indicate that a considerable volume of annual vegetation is produced on the winter range. Because the greater part of this annual vegetation does not start growing until deer are leaving the range in the spring, and because much of it is leached out and broken up before deer return in the fall, livestock get the major benefit from this class of forage on the winter range, although deer may take some of the cured cheat grass (*Bromus tectorum*). No attempt was made to measure the percentage cropping of annual vegetation. To do this adequately an additional field check would need to be made in early summer before the plants start to break up. It was decided that such a check was not of sufficient value to warrant the cost.

Shrubs

Data indicative of percentage cropping by deer and livestock of the more important shrub species on the winter range that occur in normal densities (percentage of the ground covered by herbage in normal growth patterns) of 0.1 percent or more are given in Table 10.

The utilization check indicated that bitterbrush (*Purshia tridentata*) was the most heavily cropped shrub on the winter range. This shrub was cropped by both livestock and deer. It occurs on 34 out of 50 of the check plots in the pine type where it makes up 16 percent of the perennial ground cover. In the pine type where bitterbrush forms a major fraction of the more palatable forage species, percentage cropping by livestock was 21 percent and by deer 14 percent.

The second most heavily cropped shrub, as indicated by the utilization check, was rabbitbrush (*Chrysothammus nauseosus*). It makes up 13 percent of the perennial ground cover in the grass type where it is most common.

Black sage (*Artemesia arbuscula*) was cropped an average of 0.6 percent by livestock and 0.9 percent by deer while big sagebrush (*Artemesia tridentata*) was not cropped by livestock but was cropped an average of 0.8 percent by deer. While one might expect a higher average cropping of sagebrush because of the deer stomach analysis data, it is

TABLE 10

Average Percentage Cropping of Shrubs

Range type	Average percent cropped			Number of plots on which species occurs	Percentage ground surface covered
	Livestock	Deer	Total		
Bitterbrush					
Grass	40.0	0.0	40.0	2	0.0
Pine	21.1	14.1	35.2	34	3.4
Juniper	17.9	34.4	52.3	14	1.0
Sage	9.8	23.5	33.3	9	1.0
All types	18.4	19.8	38.2	59	1.3
Rabbitbrush					
Grass	0.8	6.6	7.4	13	1.4
Pine	1.1	7.0	8.1	14	1.0
Juniper	0.3	1.5	1.8	17	1.3
Sage	0.0	0.9	0.9	9	0.7
All types	0.6	4.2	4.8	53	1.1
Black Sagebrush					
Grass	0.8	1.5	2.3	4	0.2
Pine				0	0
Juniper	0.6	1.6	2.2	31	6.0
Sage	0.3	0.9	1.2	29	11.0
All types	0.6	0.9	1.5	64	3.3
Big Sagebrush					
Grass	0.0	0.7	0.7	7	1.3
Pine	0.0	3.3	3.3	8	0.5
Juniper	0.1	1.0	1.1	19	5.7
Sage	0.0	0.5	0.5	27	10.3
All types	0.0	0.8	0.8	61	4.5

pointed out that sagebrush is a common plant on most of the range. It occurs on 117 out of 200 plots and makes up 70 percent of the perennial ground cover in the sage type, 50 percent in the juniper type, 14 percent in the grass type and 2 percent in the pine type. Hence average percentage cropping would tend to be low due to the abundance of the species.

Trees

No cropping of Ponderosa pine was recorded. Recorded livestock use of the terminal twigs of the juniper understory on the winter range was negligible. The use by deer is indicated in Table 11.

In addition to the transect segment measurements on juniper saplings and low bushy trees, data was secured from 31 tagged trees in the overstory as is shown in the table. The browse species covered above make up the bulk of this class of vegetation on the winter range.

Forbs

The only perennial forb that covered more than 0.1 percent of the ground surface on the winter range and upon which significant cropping occurred was arrowleaf balsam root (*Balsamorhiza sagittata*). The utilization check indicated that livestock cropped this plant an average of 7 percent in the pine type where it makes up nearly 3 percent of the perennial cover. The average livestock cropping for all types was 3 percent. Deer undoubtedly consumed some cured balsam root leafage during the winter of which no check was made. Because of the abnormally late growing season this spring, balsam root had just appeared above ground at the time the utilization check was made so that no spring use by deer was recorded.

TABLE 11

Average Percentage Cropping of Juniper

Range type	Percent cropped by deer	Number of plots on which species occurs
Understory		
Grass	----------	0
Pine	7.8	8
Juniper	13.2	16
Sage	0.0	4
All types	11.3	28
Overstory		
Grass	----------	0
Pine	6.5	4
Juniper	13.6	17
Sage	4.5	1
All types	11.6	22

Grasses

In order to present a tentative comparison of deer and livestock use of grasses, two assumptions have been made; viz. (1) that cropping of the young grass plants in the early spring reduces the final volume of mature grass directly and (2) that percentage cropping of grasses by deer during the 1946-47 season (which antedated the present study) was the same as that checked in the spring of 1948. All data in tables which are subject to these assumptions are enclosed with parentheses. It is well to point out again that deer also take cured grass in the fall which is not reflected in the averages.

An analysis of the cropping data on grasses indicates that the blue grasses *(Poa secunda* and *nevadensis)* are the species which deer cropped most heavily the previous spring. Poa is of common occurrence over the entire winter range appearing on 159 out of 200 plots. Blue grasses make up 40 percent of the perennial ground cover in the grass type, 11 percent in the juniper type, 10 percent in the sage type, and 5 percent in the pine type where it is the grass most heavily cropped. Average percentage cropping of Poa by livestock ranged from 6 percent in the grass type to 26 percent in the pine. This is shown in Table 12.

Squirreltail *(Sitanion hystrix)* is the second most common grass on the winter range. It occurs on 125 out of 200 plots. It is the most heavily cropped grass in the grass type.

In abundance, squirreltail is closely followed by the needle grasses (*Stipa* spp.) which appear on 112 plots. Comparative data on average percentage cropping appear in Table 12.

Idaho fescue *(Festuca idahoensis)* is less abundant on the winter range than the grasses treated above, occurring on only 56 out of 200 plots, but it is subject to the heaviest cropping in the juniper and sage types and is the second most heavily cropped grass in the grass type.

Dryland sedge (*Carex* spp.) occurs on 55 plots of which 40 are in the pine type. The utilization check indicates it is not much cropped by either deer or livestock except in the juniper type. Blue bunch wheat grass *(Agropyron spicatum)* is nearly as common as Idaho fescue but appears subject to much lighter use.

TABLE 12

Average Percentage Cropping of Grasses

Range type	Average percent cropped			Number of plots on which species occur	Percentage ground surface covered
	Livestock	Deer	Total		
Blue Grass					
Grass	(0.9)*	5.2	6.1	40	4.2
Pine	(21.5)	4.3	25.8	35	1.1
Juniper	(6.8)	5.5	12.3	44	2.7
Sage	(4.8)	2.9	7.7	40	3.5
All types	(5.6)	4.5	10.1	159	2.9
Squirreltail					
Grass	(19.5)	1.7	21.2	16	0.4
Pine	(7.2)	1.5	8.7	43	2.6
Juniper	(11.4)	1.1	12.5	32	0.8
Sage	(5.1)	2.0	7.1	34	0.9
All types	(8.7)	1.4	10.1	125	1.2
Needle Grass					
Grass	(11.9)	0.2	12.1	21	0.9
Pine	(9.2)	0.2	9.4	45	2.2
Juniper	(14.0)	1.3	15.3	30	0.9
Sage	(20.4)	0.3	20.7	16	0.3
All types	(9.1)	2.9	12.0	112	1.0
Idaho Fescue					
Grass	(17.6)	1.5	19.1	7	0.2
Pine	(4.0)	0.5	4.5	11	0.6
Juniper	(22.6)	0.6	23.2	21	0.7
Sage	(24.5)	0.1	24.6	17	0.6
All types	(17.4)	0.5	17.9	56	0.5
Carex (dry land)					
Grass		0.7	0.0	4	0.1
Pine	(1.1)	1.0	2.1	40	2.8
Juniper	(13.9)	1.1	15.0	5	0.5
Sage	(2.3)	0.0	2.3	6	0.2
All types	(3.2)	0.8	4.0	55	0.9
Blue Bunch Wheat Grass					
Grass	(3.8)	0.1	3.9	16	0.8
Pine	(2.4)	1.5	3.9	12	0.3
Juniper	(8.1)	1.1	9.2	11	0.6
Sage	(9.8)	0.1	9.9	9	0.3
All types	(5.8)	0.6	6.4	48	0.5

* Figures in parentheses are subject to the assumptions mentioned in the text.

Recommendations and Conclusions

It is evident from the data presented above that bitterbrush is the key shrub species * for both deer and livestock where it occurs in sufficient densities to be used as a base for carrying capacity. In the pine type where it makes up 16 percent of the perennial ground cover, it should be considered a key shrub beyond doubt. In the sage type where it makes up 3.3 percent and occurs on only 9 out of 50 plots and in the juniper type where it makes up 4.5 percent of the perennial ground cover and

* NOTE—The term key plant species is used here to mean forage plants for which deer and/or livestock show a decided preference and which occur in sufficient abundance to be used as a practical base for carrying capacity. Because such key species are subject to heavier use than other plants on the range, it can be assumed that where these preferred plants are not overcropped, no other plant species of significant occurrence will be generally overcropped.

occurs on 14 out of 51 plots, a decision must be made as to whether this species should be sacrificed.

If bitterbrush be eliminated as a key shrub in the juniper and sage types, juniper appears as the next most logical key browse species for deer for both types. The sage and juniper types are generally so checkerboarded throughout the winter range that juniper can well serve for both even though it has only scattered occurrence in the sage type alone.

The data indicate that the bluegrasses should be chosen as key grass species for deer on all types since they occur on 159 out of 200 plots and make up a considerable part of the perennial ground cover.

Average percentage cropping of Poa by livestock, however, is lighter than that of other grass species in all types except the pine where it may be considered the key grass species for livestock. Idaho fescue stands out as the grass with the highest average percentage cropping and should probably be considered the key grass species for livestock in the juniper type where it makes up 3 percent of the perennial ground cover and occurs on 21 out of 51 plots, and in the sage type where it makes 2 percent of the perennial cover and occurs on 17 out of 50 plots.

Squirreltail appears as a logical key grass for livestock in the grass type. It makes 4 percent of the perennial cover and occurs on 16 out of 50 plots.

If the two plant species, bitterbrush and bluegrass, that have been considered key species for both deer and livestock on the winter range in the past, be retained as primary keys wherever they occur in practical densities, the division of forage between livestock and deer the previous year may be tentatively summarized as follows:

		Average percentage cropping		
Type	*Key species*	*Livestock*	*Deer*	*Total*
Pine	Bitterbrush	21.1	14.1	35.2
All	Bluegrass	(5.6)	4.5	10.1
Over-all	Average: Both species	(9.0)	6.6	15.6

No matter which plants are chosen as key species, it is strongly recommended that the utilization check be confined to estimating percentage cropping of key species only. The mechanics of the utilization check are time-consuming. Restricting the field work and compilation to date on key species alone would reduce this semiannual job to a place where the cost in man-hours will be nominal.

It is recommended that in the future each agency supply one man trained in recognition of plant species and in estimating cropping of shrubs and herbs. Supplemental help may be added as needed to make pellet group counts or other incidental work. However, to get the most accurate data for the time spent on the project, the use of trained range examiners is warranted.

It is suggested that the volume of cured grass (some of which may well be cheat grass) and forb herbage used by deer during the winter period be balanced against the green annual forage that livestock take during the spring and early summer. It is advisable, however, to make an occasional check to determine whether deer are leaving a stubble sufficient for protection of plants and soil.

It is recognized that where such broad over-all percentage cropping averages are used as a base for management, certain portions of a range

may be deteriorating as a result of heavy use, while other areas may be used only lightly or not at all. A preliminary study has been made to determine the locations of such key areas on the winter range and cropping data should be examined in relation to these areas to determine if this is the case. Trend data when procured three to four years hence should also be studied with this in mind.

TENTATIVE KEY AREA

An analysis of the utilization check data from the forage plots on the interstate winter range suggests there is a definite key area on this range. In spite of the open winter of 1947-48, cropping of vegetation by deer on this mid-winter area was heavier than elsewhere on the range. This supports the belief that the carrying capacity of the winter range for deer should be based upon the amount of forage produced on the key area since the herd is forced to maintain itself there during critical winter periods.

Figure 27 shows the approximate boundary of the key area.

If average use of important forage species be broken into five classes (viz., lightest, lighter, average, heavier, heaviest) it will be found that 92 percent of the plots upon which cropping was heaviest are enclosed within the tentative boundary shown on the sketch map. In contrast, 91 percent of the plots on which cropping was lightest will be found outside this key area boundary. This is shown in Table 13.

A comparison of cropping by deer and by livestock on plots within the key area with cropping on plots outside the key area is shown in Table 14. The data indicate that average percentage cropping by deer averages over twice as heavy inside as outside the key area.

TABLE 13

Class of Forage Utilization Inside and Outside of Tentative Key Area

Cropping class	Number of plots	Percent of total plots in each class	
		In key area	Outside key area
Lightest	86	9	91
Lighter	35	34	66
Average	22	77	23
Heavier	12	79	21
Heaviest	13	92	8

TABLE 14

Comparison of Average Percentage Cropping Inside and Outside of Tentative Key Area

Range type	Forage species	Average percentage cropping			
		On key area		Outside key area	
		Livestock	Deer	Livestock	Deer
All	Bluegrass (Green)		10.6		3.2
All	Bitterbrush	13.8	26.7	23.2	12.1
Pine	Bitterbrush	20.5	17.4	21.5	11.1
Juniper	Juniper		19.4		6.2
Grass	Rabbit brush	1.0	7.7	0	2.3

DEER TRAPPING

The Interstate Deer Management Plan called for removal of 150 antlerless deer during the winter of 1947-48. An attempt was made to remove these deer by trapping.

The California Division of Fish and Game's big game trapping crew moved into the area on December 6, 1947, and set up three traps. These traps were variations of the Montana corral type, and consisted of 8 by 12 foot wood panels wired together to form circular corrals.

Trap number one, located at Potter Well, had four overhead gates, all of which closed simultaneously when released by a trip wire. This was the most successful trap. It caught 54 deer.

Trap number two was located on the east slope of Harvey Jones Butte, which proved a poor location. Only four deer were trapped there.

Trap number three, located in Fox Canyon, was originally constructed with swinging gates and success was poor. Later, overhead gates were installed. Subsequently, 14 deer were trapped at this location.

All traps had catch pens and loading chutes attached. Trapped animals were transported in pickup trucks to a large barn where they were held until enough were accumulated to make a two-ton truck load. Deer were ear-tagged in a squeeze chute before being transplanted to other areas. Ear-discs consisted of two-inch plastic discs and metal buttons. Red plastic discs were used on females and white on males. Females were tagged in the left ear and males in the right ear.

Success in the trapping venture was hampered by difficulties in obtaining materials for construction of the traps. It is believed that with additional traps the full quota of animals would have been secured. As it was, 72 deer were trapped in the period between January 7th and April 10th. Of this number 49 were transplanted to other areas, nine died, and 14 escaped. This resulted in removal of a total of 58 deer from the winter range. Of these animals, 22 does and 18 fawns were planted in the Providence Mountains, San Bernardino County; six does and three fawns were planted in the McDonald Peak area, Lassen County, California.

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THE GREAT WHITE SHARK *CARCHARODON CARCHARIAS* (LINNAEUS) IN CALIFORNIA WATERS DURING 1948[1]

By John E. Fitch
Bureau of Marine Fisheries
California Division of Fish and Game

On November 29, 1948, Mr. Lawrence E. Thomas of Morro Bay, California, captured an eight-foot, 400-pound great white shark in his gill nets. His nets had been set on the bottom in some twenty-six fathoms of water off Pt. Estero which is just north of Morro Bay. The remainder of the catch on that day consisted of one seven-gill shark *Notorynchus maculatus,* one soupfin shark *Galeorhinus zyopterus,* two leopard sharks *Triakis semifasciata,* one angel shark *Squatina californica,* two ratfish *Hydrolagus colliei,* one white sea bass *Cynoscion nobilis* and one California halibut *Paralichthys californicus.*

Of particular interest were the stomach contents of the great white shark. These consisted of a harbor seal *Phoca vitulina,* several five- to seven-pound rockfish *Sebastodes* sp. and the remains of several unidentifiable fish. The harbor seal weighed approximately 50 pounds and had been bitten in half just behind the shoulder girdle. The bones in the two halves had been thoroughly crushed but the seal had not been otherwise mutilated.

The great white shark ranges throughout temperate and tropical waters of the world and according to Shultz and Stern (1948) is the most formidable of all the sharks which are known to attack man. Starks (1917) states that a few specimens from Monterey Bay up to 24 feet in total length have been recorded, while one from Santa Monica Bay was said to have measured 32 feet. Walford (1935) states that this species attains a length of 40 feet and reports stomachs of specimens taken off California and Australia contained the following items: a 100-pound sea lion (California), a large Newfoundland dog (Australia) and a whole horse (Australia).

Springer (1939) reported a 15½-foot great white shark taken in Florida waters to have eaten two *Carcharinus milberti* each between six and seven feet long. He also gives very detailed measurements of this specimen. Schroeder (1938) reported a three-foot spiny dogfish and the head of an unidentified fish in the stomach of a nine-foot three-inch great white shark. The spiny dogfish had been bitten in two.

Dr. Gilbert P. Whitley, Australian ichthyologist, has listed almost one hundred fifty casualties attributed to sharks including the great white shark in temperate and tropical waters of the Australian region.

The other great white shark reported in California waters during 1948 was taken just off the pier at Scripps Institution of Oceanography, La Jolla, California. The measurements of this specimen are published here through the kindness and courtesy of Mr. J. L. McHugh of that

[1] Submitted for publication January, 1949.

FIGURE 28. Eight foot great white shark on dock at Morro Bay.
Photograph by Lawrence E. Thomas

institution. The shark was taken by Mr. Boley Ramsower on hook and line July 21, 1948, and was measured and recorded in the Scripps Institution field book under number H48-194 by Mr. J. L. McHugh.

FIGURE 29. Side view of four and one-half foot great white shark taken at La Jolla, California. *Photograph by Paul Williams, Scripps Institution of Oceanography*

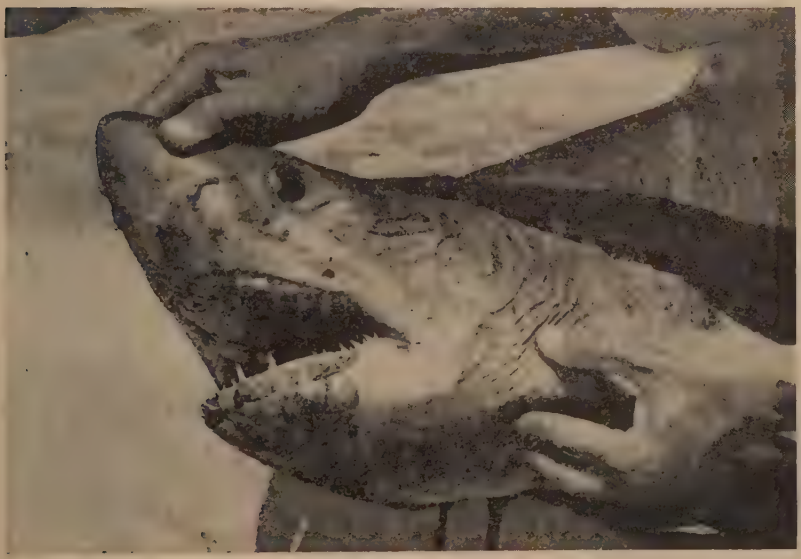

FIGURE 30. Front view showing dentition of La Jolla specimen. *Photograph by Paul Williams, Scripps Institution of Oceanography*

The following measurements, all in millimeters, are given in order to supplement the all too limited data on this species.

Length of fork of tail	1,365
Length of tip of upper lobe of caudal	1,543
Length of tip of lower lobe of caudal	1,479
Snout to anterior fleshy border of orbit	96
Horizontal diameter of eye	24
Vertical diameter of eye	22.5
Tip of snout to anterior edge of nostril	66
Vertical length of nostril	22
Length of gill slits	
1	140
2	140
3	143
4	145
5	155
Snout to insertion of pectoral	435
Length of pectoral (insertion to tip of outer lobe)	330
Snout to insertion of dorsal	571.5
Dorsal base	149
Insertion of dorsal to tip of anterior lobe	200
Posterior end of dorsal base to insertion of dorsal finlet	336
Base of dorsal finlet	20
Base of pectoral	108
Snout to insertion of pelvic	876
Pelvic base	89
Anterior border of anus to insertion of ventral finlet	216
Base of ventral finlet	20
Width of mouth at angle (fleshy part)	127

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NOTES

A NEW HOST FOR THE EYE WORM *THELAZIA CALIFORNIENSIS*

In a previous article (Cal. Fish and Game, 1944, vol. 30, pp. 58-60) the author reviewed the occurrence of the eye worm, *Thelazia californiensis,* in deer in California and cited the published reports from other animals which included the cat, dog, sheep, bear and man. During the past year several specimens of these worms collected from the eyes of coyotes *(Canis latrans)* have been submitted to the Laboratory of the Bureau of Game Conservation. These specimens were collected by state trappers as follows: specimens from coyote in the vicinity of Big Bear Lake, San Bernardino County, by Wesley Mongey; from Santa Barbara County by Carl Tegen; and from San Simeon, San Luis Obispo County, by John B. Johnson.

This is believed to be the first report of *T. californiensis* from the coyote.—*Carlton M. Herman, Bureau of Game Conservation, California Division of Fish and Game, January, 1949.*

IN MEMORIAM

AUGUST BADE

August Bade, chief of the Bureau of Game Farms at the time of his retirement from the Division of Fish and Game April 1, 1946, passed away in Napa on February 11, 1949.

"Gus" was born at Milton, Oregon, on March 20, 1875. In the early 1920's he was invited by the Fish and Game Commission to survey the game bird situation in California. As a result of this survey, in 1925 Mr. Bade was hired to develop our game farm program. He started as Superintendent of the Yountville Game Farm and pioneered the system of upland game bird propagation we now use. In 1926, the Yountville farm liberated 3,023 birds. By 1946, the program had expanded to nine game farms which liberated a total of 57,463 birds.

Much of his time was spent with sportsmen's and service clubs, bringing to their attention the value of upland game birds. He had many friends throughout the State who will mourn his passing.

REVIEWS

Road to Survival

By William Vogt. William Sloane Associates, New York. 1948. 335 pp. $4.

This book should be a "must" for every citizen of our country. It presents a vivid picture of the status of some of our natural resources, particularly those that have a bearing on man's food supply. While the author presents a very pessimistic view of our land and agricultural resources which has been opposed in a number of other reviews and discussions of this book, the facts are documented and conclusively presented. It is a book well worth the reading time it requires.—*Carlton M. Herman, California Division of Fish and Game.*

My Land and Your Land Conservation Series

National Wildlife Federation, Inc., 3308 14th Street, N. W., Washington, D. C. 1941, 1942.

In view of the frequent requests for literature on the grade school level we take this opportunity to call to the attention of our readers interested in such material, four little booklets published by the National Wildlife Federation.

1. Would you like to have lived when—? This was written for grades 3, 4 and 5. This booklet (32 pages), discusses the history of our country from the time of the first settlers, the utilization and abuses of our natural resources. It is an excellent introduction to conservation.

2. Raindrops and Muddy Rivers (32 pages). This was written for grades 4, 5 and 6. It is an introduction to water utilization and conservation.

3. Plants and Animals Live Together (48 pages). For grades 5, 6 and 7. This booklet presents the problems of forest and wildlife conservation.

4. Nature's Bank—The Soil (48 pages). For grades 6, 7 and 8. This booklet is an excellent coverage of the subject of soil conservation.

These booklets should prove of great value as teaching aids. They can be readily obtained by writing to the National Wildlife Federation.—*Carlton M. Herman, California Division of Fish and Game.*

How to Know the Birds

By Roger Tory Peterson. The New American Library of World Literature, New York, a Mentor book, 1949, 144 pp., 35c.

This little book, written by a widely known authority of bird identification, is an excellent introduction and aid to bird recognition. It is profusely illustrated by the author with black and white drawings and also shows many of the birds in silhouette as an aid in recognition by shape. This book should prove of great value as a teaching aid, particularly in the grade school level but also has much of merit for the older as well as the more experienced bird watcher.—*Carlton M. Herman, California Division of Fish and Game.*

REPORTS

SEIZURES OF FISH AND GAME

October, November, December, 1948

Fish:	
Abalone	351
Bass	145
Bluegill	73
Crabs	21
Clams	2,192
Catfish	120
Catfish, pounds	360
Cockles	5,567
Halibut, pounds	110
Lobsters	389
Lobster, pounds	1,141
Steelhead	6
Salmon	55
Trout	345
Yellowtail, pounds	3,142
Sardines, tons	697½
Game:	
Deer	122
Deer meat, pounds	1,340
Doves	622
Ducks	1,612
Coots	97
Bear meat, pounds	10
Elk meat, pounds	400
Geese	91
Grebe	13
Muskrats	11
Pine Marten	1
Sagehen	1
Tree Squirrels	9
Pheasants	177
Rabbits	12
Swans	9
Quail	48
Shorebirds	13
Non-game	4
Pigeons	7

FISH CASES

October, November, December, 1948

Offense	Number arrests	Fines	Jail sentences (days)
Abalones: Undersize; without permit	22	$830 00	4
Bass: Undersize; overlimit; at night; offering prizes	68	1,558 00	
Catfish: Undersize; overlimit	9	185 00	
Clams: Undersize; overlimit; at night	127	3,302 50	25
Crabs: Taking females; undersize	2	50 00	
Cockles: Overlimit	15	375 00	
Chumming: Salmon egg cluster	1	50 00	
Steelhead: Other than angling	2	20 00	
Trout: Overlimit; 2 lines	11	535 00	
Salmon: Snagging; overlimit; shooting; spawning area; possession illegally taken; spearing	56	2,110 00	
Lobsters: Undersize; oversize; operating traps closed district; bating traps with abalone	29	1,030 00	
Commercial: Round haul net, district 20; no license; undersize fish; trawl nets closed district; no dealer's license; no boat registration; failure to issue receipts	94	4,365 00	
Licenses: Transfer, non-resident using resident license; false statement to procure license	17	465 00	
Pollution: Oil; fish bilge; sawdust	17	1,815 00	
Angling: Spearing; set line; 300 ft. of stream illegal gill net	193	3,931 00	
Totals	663	$20,621 50	29

Court forfeitures:
Undersized sardines $33,417 51

GAME CASES

October, November, December, 1948

Offense	Number arrests	Fines	Jail sentences (days)
Deer: Spike buck; doe; overlimit; transfer of tags; failure to retain antlers; transporting without permit; possession fawn; defacing tag; tagging another's deer; "A" tag one deer district	226	$20,210 00	416
Deer meat: Possession, closed season	25	1,315 00	60
Ducks: Closed season; in refuge; overlimit; failure to show; unplugged gun; no duck stamp; poisoning	310	16,540 00	.....
Doves: Late shooting; closed season	58	2,320 00	.....
Bear meat: Closed season	1	20 00	.....
Elk: Possession	2	500 00	.....
Geese: Closed season; late shooting	22	1,075 00	.....
Muskrats: Closed season	1	10 00	.....
Squirrels: Possession, closed season	5	295 00	.....
Pine marten: Closed season	1	100 00	.....
Grebe: Possession	1	50 00	.....
Coots: Closed season; overlimit	9	275 00	.....
Antelope: Possession	1	350 00	.....
Swans: Possession	9	518 00	.....
Shorebirds: Killing	11	235 00	10
Quail: Closed season; from automobile; rifle	20	1,505 00	.....
Rabbits: Closed season; unplugged gun	12	480 00	.....
Pigeons: Closed season; rifle	5	175 00	.....
Pheasants: Closed season; hen; trapping; from auto	152	9,579 00	.....
Non-game: Killing	7	185 00	.....
Hunting: No license; from highway; at night; in refuge; metal jacketed bullets; power boat; spotlighting; unplugged gun	527	20,885 00	11½
Totals	1,463	$78,942 00	497½

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STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF FISH AND GAME
San Francisco, California

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CALIFORNIA FISH AND GAME

"CONSERVATION OF WILDLIFE THROUGH EDUCATION"

VOLUME 35 ISSUED JULY 6, 1949 No. 3

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